MOMRA
Bridges, Tunnels, Culverts and Pedestrian Bridges Specifications in Urban Areas

Construction Specifications

MA 100-C-V1/1

2013
Introduction

As for the importance and vitality of road constructions and the need to control them so as to perform their function in an appropriate way throughout their service age. So many countries and Organizations had prepared specifications for design and construction these structures. These Specifications were differed from one another according to the environment and the nature of the climate. For instance some organizations and societies in U.S.A. Such as the American Association of State Highway and Transportation Officials (AASHTO). These organizations and societies have improved and updated design specification. In the same way each state in U.S.A. has developed its own specification mainly based on AASHTO specification and refers to them in different situations, but they will be suitable for the circumstances of the State that has improved them. As for K.S.A. which is one of the countries that has a large transportation network and many road structures, so the necessity arose to prepare suitable specification for these structures to suit the environmental circumstances and the transportation policy that has adopted in K.S.A. So the Kingdom of Saudi Arabia representative in the Ministry of Municipal and Rural Affairs has taken the role of collecting the specification under the title Bridges, Tunnels, culverts, pedestrian bridges in the urban areas.

These specifications include the following:
1- Preliminary studies
2-Design specifications
3-Construction specifications

The ministry has also updated codes for both bridges and culverts manuals according to the new specifications.
## Specifications Books

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SECTION 1. ABBREVIATIONS AND DEFINITION OF TERMS

1.1. General
Wherever the following terms or abbreviations or pronouns in place of them are used in these Specifications or in other contract documents, the intent and meaning shall be interpreted in Articles 1.2 and 1.3.

1.2. Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
</tr>
<tr>
<td>ACI</td>
<td>American Concrete Institute</td>
</tr>
<tr>
<td>AF&amp;PA</td>
<td>The American Forest &amp; Paper Association</td>
</tr>
<tr>
<td>AISI</td>
<td>The American Iron and Steel Institute</td>
</tr>
<tr>
<td>AISC</td>
<td>American Institute of Steel Construction</td>
</tr>
<tr>
<td>ANSI</td>
<td>American National Standards Institute</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>AWS</td>
<td>American Welding Society</td>
</tr>
<tr>
<td>BS 6164</td>
<td>Code of Practice for Safety in Tunneling in the Construction Industry</td>
</tr>
<tr>
<td>CIRIA</td>
<td>Construction Industry Research and Information Association</td>
</tr>
<tr>
<td>CRSI</td>
<td>Concrete Reinforcing Steel Institute</td>
</tr>
<tr>
<td>DIN</td>
<td>German Institute of Standards</td>
</tr>
<tr>
<td>FHWA</td>
<td>Federal Highway Administration</td>
</tr>
<tr>
<td>ICR</td>
<td>International Concrete Repair Institute</td>
</tr>
<tr>
<td>ISO</td>
<td>International Standards Organization</td>
</tr>
<tr>
<td>IWRC</td>
<td>Independent Wire Rope Core</td>
</tr>
<tr>
<td>NACE</td>
<td>National Association of Corrosion Engineers</td>
</tr>
<tr>
<td>NATM</td>
<td>New Austrian Tunneling Method</td>
</tr>
<tr>
<td>NDS</td>
<td>News Digital Systems</td>
</tr>
<tr>
<td>PCI</td>
<td>Pre-stressed Concrete Institute</td>
</tr>
<tr>
<td>PVC</td>
<td>Polyvinyl Chloride</td>
</tr>
<tr>
<td>RMR</td>
<td>Rock Mass Rating</td>
</tr>
<tr>
<td>SASO</td>
<td>Saudi Arabian Standards Organization</td>
</tr>
<tr>
<td>SBC</td>
<td>Saudi building code</td>
</tr>
<tr>
<td>SSPC</td>
<td>Steel Structures Painting Council</td>
</tr>
</tbody>
</table>
1.3. Terms

1.3.1. Acceptance Plan
A prescribed method of sampling, measuring and testing together with criteria for the acceptability of a lot of material or construction.

1.3.2. Acceptable Quality Level AQL
The level of Lot percent defective at/or below which the work is considered to be satisfactory.

1.3.3. Acceptance Program
All factors comprise the agency's determination of the degree of compliance with contract requirements and value of a product. These factors include agency or agency supervised sampling, testing, measuring, and inspection.
These factors should also include validated results of Contractor sampling and testing.

1.3.4. Additive
A substance or agent added in small amounts to a basic ingredient of a mixture prior to mixing.

1.3.5. Addendum
A written amendment or revision to the Contract Documents or plans issued to bidders subsequent to the date of advertisement and prior to the final date and time for submission of Tenders indicated in the "Instructions to Tenderer."

1.3.6. Advertisement for Bids or Notice to Contractors
A public announcement inviting bids for work to be performed or materials to be furnished, as required by law.

1.3.7. Article
An immediate subheading of a section of these Specifications consisting of Subarticles, Items, Subitems and/or paragraphs which set forth details and requirements essential or necessary to form the Specifications. Specifications are divided into Divisions, Divisions into Sections, Sections into Articles, Articles into Subarticles, Items, Subitems and paragraphs.

1.3.8. Award
The acceptance by the Director of the proposal of the lowest responsible bidder, as required by law.
1.3.9. **Backfill**
Material used to replace or the act of replacing material removed during construction; also may denote material placed or the act of placing material adjacent to structures.

1.3.10. **Back Slope**
In cuts, the slope from the bottom of the ditch to the top of cut.

1.3.11. **Bid**
See Tender.

1.3.12. **Bidder**
An individual, firm, partnership, corporation or any acceptable combination thereof submitting a bid for the advertised work.

1.3.13. **Binder Layer**
The lower layer of the surface, consisting of a plant mix of graded aggregate and bituminous material.

1.3.14. **Bill of Quantities**
That portion of the Contract Documents showing all items of Work as well as estimated quantities and contract unit prices for those items.

1.3.15. **Bridge**
Any structure having an opening not less than 6.1 m that forms part of a highway or that is located over or under a highway.

1.3.16. **Bridge Length**
The length of a bridge structure is the over-all length measured along the line of survey stationing back to back of backwalls of abutments, if present; otherwise, end to end of the bridge floor; but in no case less than the total clear opening of the structure.

1.3.17. **Bridge Roadway Width**
The clear width measured at right angles to the longitudinal centerline of the bridge between the bottom of curbs or guard timber risers.

1.3.18. **Boulder**
A rock fragment, usually rounded by weathering or abrasion, which will be retained on a seventy-five 75 millimeter sieve

1.3.19. **Calendar Day**
Every day shown on the calendar, beginning and ending at midnight.

1.3.20. **Calibrate**
1. To determine settings of the plant which will provide correct proportions of the components of plant-mixed materials.
2. To compare with a standard or check the graduations of a gauge or other measuring devices.
1.3.21. Camber
A slight arch designed or built into a structure to compensate for the natural deflection after loading.

1.3.22. Centerline
The defined and surveyed line shown on the plans from which the highway construction is controlled.

1.3.23. Certificate of Guarantee
A signed statement by a person having legal authority to bind a company or supplier to its product. Such certificate shall state that the material specifications and test results are in compliance with the specified requirements of the pertinent AASHTO, ASTM and/or other designations.

1.3.24. Compaction
The active or mechanical consolidation of a mass by rolling, tamping or other similar means.

1.3.25. Construction Joint
A joint made necessary by a prolonged interruption in the placing of concrete.

1.3.26. Consecutive Days
Two or more calendar days, one is following the other.

1.3.27. Contract and Contract Documents
The written agreement between the Ministry of Municipality and Rural Affairs and the Contractor setting forth the obligations of the parties hereunder for the performance of the prescribed work.

The Contract includes the proposal, contract forms and contract bonds, specifications, supplemental specifications, special provisions, general and detailed plans, and notice to proceed, also any change orders and supplemental agreements that are required to complete the construction of the work in an acceptable manner, including authorized extensions thereof, and such other documents as by law or references are made a part thereof, all of which constitute one instrument.

1.3.28. Contract Bid Price
The sum total of the products of the approximate quantities of the items of the work listed in the proposal and the respective unit prices bid in the proposal.

1.3.29. Contract Bonds
The approved bonds furnished and executed by the Contractor and his surety to guarantee completion of the contract in accordance with its terms.

1.3.30. Contract Item (Item of Work)
A specifically described unit of work for which a unit price is provided in the Contract Documents.
1.3.31. **Contract Time**

The time allowed for completion of the contract, including authorized time extensions. When a calendar date of completion is shown in the Tender, in lieu of the number of working or calendar days, the contract time is the period between the Process Verbal for Handing over the Site to the date of completion.

1.3.32. **Contractor**

The individual, firm or corporation contracting with the MOMRA for performance of the Work described in the Contract Documents.

1.3.33. **Contract Payment Bond**

The bond furnished by the Contractor and his surety to guarantee payment of the debts covered by the bond.

1.3.34. **Contract Performance Bond**

The bond furnished by the Contractor and his surety to guarantee performance of the work in accordance with the contract.

1.3.35. **Contract Sum or Contract Amount**

The total contract bid price, revised to include changes caused by overruns and underruns in contract items, plus the sum of all approved supplemental agreements and force account orders.

1.3.36. **Country**

The country or Districts of Kingdom of Saudi Arabia in which work herein specified is to be performed.

1.3.37. **Culvert**

Any structure under the roadway with a clear opening of 6.1 meters or less measured along the center of the roadway.

1.3.38. **Date**

Day, month and year reckoned according to the Hegira calendar and the applicable date corresponding to the Gregorian calendar.

1.3.39. **Deck**

The surface layer of concrete and reinforcing steel on a bridge.

1.3.40. **Density**

The mass per unit volume of material, usually expressed in kilograms per cubic meter or grams per cubic centimeter.

1.3.41. **Design Mix**

See Job Mix.

1.3.42. **Design Load**

The maximum anticipated loads that must be supported by a structure.
1.3.43. **Detour**
   A temporary rerouting of traffic.
   The route of the temporary rerouting.

1.3.44. **Directive**
   An official written communication, having contractual status, from the Engineer to the Contractor with respect to any or all phases of the Contract and Work including, but not limited to, progress, approvals, rejections, procedures, methods, safety, etc.

1.3.45. **Dowel**
   A load transfer element usually consisting of a plain round steel bar.

1.3.46. **Drawings**
   See Plans.

1.3.47. **Elevation**
   Height above sea level or other datum.

1.3.48. **Engineer**
   The duly authorized representative of the Ministry at the project site, acting directly or through his duly authorized representatives, who is responsible for engineering supervision of the Work.

1.3.49. **Equipment**
   All machinery and equipment, together with the necessary supplies for operation and upkeep, maintenance, and protection, and also tools and apparatus necessary for the proper construction and acceptable completion of the work.

1.3.50. **Existing**
   The physical status as of the date of the invitation for bids of any structure, base, surface, sub-grade, road, bridge, detour, or other unit affected by a particular project or designated highway.

1.3.51. **Expansion Joint**
   A joint located to provide for expansion of a rigid slab, without damage to itself, adjacent slabs, or structures.

1.3.52. **Extra Work**
   Additional or new work not provided for in the Contract as awarded but subsequently ordered by the Ministry for the satisfactory completion of a project within its intended scope.

1.3.53. **Extra Work Order**
   A change order concerning the performance of work or furnishing of materials involving extra work. Such extra work may be performed at agreed prices or on a force account basis as provided elsewhere in these specifications.

1.3.54. **Faulting**
   Differential vertical displacement of rigid slabs at a joint or crack.
1.3.55. Force Account Work
Work paid for by reimbursing for the actual costs for labor, materials, and equipment usage incurred in the performance of the work, as directed, including a percentage for overhead and profit, where appropriate.

1.3.56. General Specifications
A group of technical requirements and conditions describing the works required to be constructed, construction methods, equipments, materials, analysis methods, quality control procedure, quality assurance procedure and acceptance methods.

1.3.57. Grout
Mortar, composed of sand, cement, and water of such consistency that it can easily be placed by pouring or pumping if necessary.

1.3.58. Guarantor
A bank approved by the Government of Saudi Arabia, which provides the guarantees called for in the Contract Documents.

1.3.59. Holiday
See "Legal Holiday".

1.3.60. Headwall
A wall, at the end of a culvert to prevent earth from spilling into the channel.

1.3.61. Inspector
The Engineer's authorized representative assigned to make detailed inspection of the work.

1.3.62. Item of Work
See Contract Item.

1.3.63. Job-Mix job-mix formula, design-mix
The exact proportions of all components of a bituminous or other type mix, determined by laboratory tests.

1.3.64. Joint
A designed vertical plane of separation or weakness.

1.3.65. Kingdom
The Kingdom of Saudi Arabia.

1.3.66. Laboratory
The testing laboratory of the Department or any other testing laboratory which may be designated by the Engineer.

1.3.67. Legal Holidays
All recognized holidays, national holiday, days of rest, and other religious customs officially recognized by the Kingdom.
1.3.68. **Leveling Course**  
The layer of material placed on an existing surface to eliminate irregularities prior to placing an overlaying course.

1.3.69. **Load Transfer Device**  
A mechanical means designed to carry loads across a joint.

1.3.70. **Longitudinal Joint**  
A joint normally placed between traffic lanes to control longitudinal cracking.

1.3.71. **Lot**  
A discrete quantity of material or work to which an acceptance procedure is applied.

1.3.72. **Major Item**  
Any item having an original contract value in excess of 10 percent of the total contract bid price.

1.3.73. **Materials**  
Any substances specified for use in the construction of the project and its appurtenances.

1.3.74. **Ministry**  
Ministry of Municipalities and Rural Affairs (MOMRA).

1.3.75. **Municipality Amanah**  
A service system of a legal entity has financial and administrative independence headed by an official called secretary who carries out its delegated duties specified by assignment resolutions.

1.3.76. **Municipality of province Baladiah**  
A legal entity of financial and administrative independence has its own separate budget and serves the city and related villages established by a Ministerial resolution issued by the Minister of Municipal and Rural Affairs.

1.3.77. **Minor Concrete**  
Nonstructural concrete as designated on the plans or in the specifications.

1.3.78. **Moisture Content**  
The percentage, by weight, of water contained in soil or other material, usually based on the dry weight.

1.3.79. **Original Ground**  
The ground surface just prior to the initiation of the proposed work.

1.3.80. **Performance Guarantee**  
The approved form of security, executed by the Contractor and his Surety or Sureties, guaranteeing complete execution of the Contract and all supplemental agreements pertaining thereto, and the payment of, all legal debts pertaining to the construction of the project.
1.3.81. Period of Maintenance

Period of maintenance shall mean the period of Contractor maintenance named in the Contract, calculated from the date of completion of the Work as certified by the Provisional Handover Committee.

1.3.82. Plans

The contract drawings, which show the location, character, dimensions, and details of the prescribed work, including layouts, profiles, cross sections, and other details or reproductions thereof.

1.3.83. Price Breakdown

The Contractor's proposal that submitted to the Ministry which shows the costs of all items indicated in the Bill of Quantity and describes the details contents of cost for each work item.

1.3.84. Preconstruction Conference

A conference arranged by the Engineer between himself and representatives of the Contractor before Work begins to discuss schedule of progress and contract administration requirements.

1.3.85. Program of Work

A work schedule prepared and submitted by the Contractor to the Engineer for his approval prior to the commencement of the Work. The Program shall show the equipment, the order of procedure, and methods which the Contractor proposes to use to carry out the Work.

1.3.86. Process-Verbal

Any written statement of record concerning the Works of the Contract signed by the Engineer and the Contractor.

1.3.87. Professional Engineer

Engineers who hold valid State licenses permitting them to offer engineering services directly to the public, who are experienced in the work for which they are responsible, who take legal responsibility for their engineering designs, and who are bound by a code of ethics to protect the public health.

1.3.88. Provisional Handover

A conditional acceptance, by the Ministry, of a partial or total completion of the Work as authorized in the General Conditions of the Contract.

1.3.89. Proposal

The offer of a bidder, on the prescribed form, to perform the stated construction work at the prices quoted.

1.3.90. Proposal Form

The prescribed form on which the offer of a bidder is to be submitted.
1.3.91. **Quality Assurance**
A group of planned regulatory procedures for taken measurements and samples, testing and evaluation for tests and measurements results, in order to provide satisfactory confidence to assure that the constructed works conforming to the specified requirements in the specifications, these regulations shall be applied by the Ministry or specialized firms assigned by the ministry.

1.3.92. **Quality Assurance Procedures**
Specific sampling, testing, measuring, and evaluation procedures for determining the degree of conformance to the quality and quantity requirements of the Specifications.

1.3.93. **Quality Control**
A set of specific procedures for measurements, samplings, testing, and evaluation of tests and measurements results carried to determine the degree of compliance with quality requirements and standards indicated in the specifications and implemented by the Contractor.

1.3.94. **Quality Index**
A statistic computed when applying the variables acceptance procedures to estimate the level of quality actually achieved.

1.3.95. **Questionnaire**
The specified forms on which the Contractor shall furnish required information as to his ability to perform and finance the work.

1.3.96. **Random**
Without bias or regularity.

1.3.97. **Rural council**
A legal entity of financial and administrative independence and has its own budget formed to serve a group of villages and its head office shall be located in one of those villages.

1.3.98. **Rejectable Quality Level  RQL**
The level of Lot percent defective at/or above which the work is considered to be unacceptable.

1.3.99. **Reinforcement**
Steel embedded in a rigid pavement slab and in concrete structures to resist tensile stresses and detrimental opening of cracks.

1.3.100. **Reprocessing**
The renewal of an existing surface by scarifying, remixing with or without additional material, and relaying.

1.3.101. **Resurfacing**
The placing of one or more new courses on an existing surface.
1.3.102. Right-of-Way
The publicly owned land acquired for and devoted to the highway and its appurtenances.

1.3.103. Riprap
A protective covering of graded boulders, pieces of concrete or stone, with or without mortar, to prevent erosion.

1.3.104. SABKHA
Sabkhas are salt bearing arid climate sediments covering vast areas of the coasts of Saudi Arabia.

1.3.105. Shop Drawings
Fabrication plans for any part of the work including, but not limited to, precast concrete items, structural steel items, or other metal items, and connections thereof, which the Contractor is required to submit to the Engineer.

1.3.106. Sidewalk
That portion of the roadway primarily constructed for the use of pedestrians.

1.3.107. Site
The lands and other places provided by the Ministry for the execution of the Work.

1.3.108. Site Engineer
He on-site representative of the Contractor duly authorized to receive and execute all instructions of the Engineer and to supervise and direct all of the Contractor's construction operations in all phases of the Work.

1.3.109. Skew Angle
The complement of the acute angle between two centerlines which cross; for a structure centerline, skew right means the right side of the structure is ahead; skew left means the left side of the structure is ahead.

1.3.110. Specifications
The formal directions, provisions, and requirements which outline the Work to be done, the way in which it is to be done, the character of materials and mixtures to be used, or the results to be obtained.

1.3.111. Special Specifications
Additions and revisions to the General and Supplemental Specifications covering conditions peculiar to an individual project.

1.3.112. Specified Completion Date
The date on which the contract work is specified to be completed.

1.3.113. Standard Drawings
Drawings approved for repetitive use, showing details to be used where appropriate.
1.3.114. **Standard Specifications**
   A book of specifications approved for general application and repetitive use.

1.3.115. **Subcontractor**
   An individual, firm or corporation to whom the Contractor sublets part of the Work.

1.3.116. **Substructure**
   All of that part of the structure below the bearings of simple and continuous spans, skewbacks of arches and tops of footings of rigid frames; including backwalls, wingwalls, and wing protection railings.

1.3.117. **Superintendent**
   The Contractor's authorized representative in responsible charge of the work.

1.3.118. **Superstructure**
   The entire structure except for the substructure.

1.3.119. **Superelevation**
   The increasing of the cross slope on a curve to partially offset the centrifugal force generated when a vehicle rounds the curve.

1.3.120. **Supplemental Agreement**
   A written agreement with the Contractor covering changes in the plans, specifications, or quantities or any combination thereof, within the scope of the contract and establishing the basis of payment and time adjustments for the work affected by the changes.

1.3.121. **Supplemental Specification**
   Additions and revisions to the General Specifications that are adopted subsequent to issuances of the printed book.

1.3.122. **Surety**
   The corporation, partnership, or individual other than the Contractor, executing a tender Guarantee furnished by the Contractor.

1.3.123. **Temporary Structure**
   Any structure required to maintain traffic during construction of the work, which will be dismantled if required when the work is completed.

1.3.124. **Tender**
   The bid or offer made by a bidder, on the prescribed form, to perform the Work and to furnish the labor and materials at the prices quoted.

1.3.125. **Tender Documents**
   The approved form on which the Ministry requires Tenders to be prepared and submitted for the Work.
1.3.126. Tender Guarantee

The security furnished with a Tender to guarantee that the bidder will enter into contract if his Tender is accepted, and includes the specified forms on which the Contractor shall furnish required information as to his ability to perform and finance the Work.

1.3.127. Tenderer

See Bidder.

1.3.128. Traffic Lane

The portion of a traveled way for movement of a single line of vehicles.

1.3.129. Visual Inspection

Inspection for defects which can be seen.

1.3.130. Water-Cement Ratio

The ratio of the amount of water, exclusive of that absorbed by the aggregates, to the amount of cement in a concrete or mortar mixture; preferably stated as a decimal by mass.

1.3.131. Weephole

A hole through an abutment or retaining wall to relieve hydrostatic pressure from groundwater.

1.3.132. Work

Work shall mean the furnishing of all labor, materials, equipment, and other incidentals necessary or convenient to the successful completion of the project and the carrying out of all duties and obligations imposed by the contract.

1.3.133. Working Day

A working day shall be any day upon which the Contractor can physically and legally prosecute the Work.

1.3.134. Working Drawings

Stress sheets, shop drawings, erection plans, falsework plans, framework plans, cofferdam plans, bending diagrams for reinforcing steel, or any other supplementary plans or similar data which the Contractor is required to submit to the Engineer for approval.
1.4. REFERENCES


MOT KSA;"General Specifications For Road And Bridge Construction"; November 1998.

SECTION 2. INSTRUCTIONS TO BIDDERS

2.1. Proposal Requirements And Conditions

2.1.1. Notice to Contractors  Advertisement

Invitation for tenders and submission of proposals shall be conducted in compliance with regulations and laws implemented in KSA, specifically the latest issue of the form of the general works contract, and regulations for provision of government purchases and execution of its projects and works.

Whatever is not stipulated in this division or contradicts with what is indicated in the general works contract form and regulations for the provision of government purchases and execution of its works and projects, is subject to the general works contracts regulations and regulations for the provision of government purchases and execution of its projects and works.

2.1.2. Language of bid

Arabic Language is the approved language for the interpretation of the bid and all correspondence between the ministry and Contractors, and all documents proposals shall be submitted in Arabic language.

2.1.3. Competition documents

Before he submits his proposal, Contractor shall review drawings and documents which are the subject of the bid he intends to submit. He shall examine and audit these and enquire about all the details. Also, he shall provide his comments and opposition against them within the period specified in the invitation.

Contractor is considered, immediately at submitting his proposals, that he has studied, understood, conceived, and accepted all the articles of the tender.

He has no right to oppose or claim any additional costs arising from undue assumption of non-clarity or misunderstanding or not reviewing competition documents or contract or work drawings, specifications, details, and sites. All participants in the competition shall enclose all the documents indicated in the announcement with their proposals. And the Ministry has the right of rejecting any bid that has not completed those documents.

2.1.3.1. Competition documents include

An introduction letter showing that Contractor has studied competition documents, terms and conditions and his commitment to all the instructions and conditions indicated in them. The letter shall be signed and stamped from the Contractor.

1. A copy of the invitation announcement.
2. A copy of a valid Commercial Registration certificate.
3. A copy of a valid Chamber of Commerce membership certificate.
5. A copy of valid Classification certificate.
6. A description of Contractor's previous works.
7. Any other documents indicated in the announcement.
Section 2: Instructions to Bidders

8. A valid bank guarantee for 1% of the tender value for a period not less than three months.

2.2. Contract Rates

Contractor shall submit his rates in Saudi Riyals and no other currency is acceptable. Prices shall be written by ink can not be canceled in words and figures showing unit prices for each work item according to the measuring units indicated in the BOQ. Total amounts shall be shown for each work item after multiplying the unit price by the estimated quantity, also total proposal price resulting from all total prices of all work items.

When there is a difference in the bid between unit price and total price, the unit price is the one to be applied, but if there is a difference between figures and wordings, the latter is applied.

It is not permissible to cancel or amend on the BOQ, and when it is necessary Contractor may cancel then write the correct rate in red color providing that he signs and stamps besides cancellation.

Prices shall be based on a study made by the Contractor for work items, his review for contract documents and work site, materials sources and prices for all the works. The information indicated in the invitation or special specifications, general specifications, drawings, materials availability, soil and site condition are considered as inferential and shall not be taken as a basis for price estimations. Contractor shall base his prices on his own studies, and no objection concerning this will be accepted after proposal submission.

Contractor shall submit together with BOQ another table showing constituents of each price for each work item.

Prices specified in the tender are considered as a basis for contract prices in case tender has been awarded according to them. They shall include submission of labor, materials, mixes, machines, equipments, conducting measurements and testing, report submissions, all third party charges, expenses, and payments, and all other requirements for the completion of the works in accordance with contract, drawings, special and general specifications.

2.2.1. PRELIMINARY GUARANTEE

Contractor, together with his proposal, shall submit an unconditional preliminary letter of guarantee issued from one of the banks approved by SAMA Saudi Arabian Monitory Agency valid for the period indicated in the invitation announcement, providing that it is not less than 3 months, with the value of one percent 1% of the contract total value or for the value indicated in the announcement. The Ministry shall not consider any proposal that does not include the L/G Letters of Guarantee.

2.2.2. Final Guarantee

Contractor who has been awarded the contract, on the basis of the award letter, and within 10 days from receiving award letter, shall submit to the ministry an irrevocable bank guarantee issued in its benefit from an approved bank at SAMA for this purpose, it shall be in the value of five percent 5% of the contract total value, or the value specified in the contract.
2.3. Interpretation Of Quantities In Bid Schedule

The quantities appearing in the bid schedule are approximate only and are prepared for the comparison of bids. Payment to the Contractor will be made only for the actual quantities of work performed and accepted, or materials furnished, in accordance with the contract. The scheduled quantities of work to be done and materials to be furnished may each are increased, decreased, or omitted as provided herein.

2.4. Examination Of Plans, Specifications, Special Provisions, And Site Of Work

Before submitting a proposal, bidders shall examine carefully the site of the proposed work, the general and local conditions, the proposal form, standard specifications, supplemental specifications, special provisions, and the bid bond form, and it is mutually agreed that the submission of a proposal shall be prima facie evidence that the bidder has made such examination and has judged for and satisfied himself as to the conditions to be encountered in performing the work, and to the requirements of plans, standard specifications, supplemental specifications, special provisions, contract, and bonds. No adjustments or compensation will be allowed for losses caused by failure to comply with this requirement.

Boring logs and other records of subsurface investigations are available for inspection by bidders. It is understood that such information was obtained and is intended for Ministry design and estimating purposes only. It is made available to bidders that they may have access to identical subsurface information available to the Ministry, and is not intended as a substitute for personal investigation, interpretations and judgment of the bidders.

Bidders are advised that the Ministry disclaims responsibility for any opinions, conclusions, interpretations, or deductions that may be expressed or implied in any of the information presented or made available to bidders; it being expressly understood that the making of deductions, interpretations, and conclusions from all of the accessible factual information is the bidder's sole responsibility.

2.5. Preparation Of Proposal

2.5.1. Proposal Form

The bidder's proposal must be submitted on the complete original proposal form. Proposal forms are numbered serially and are not transferable.

2.5.2. Signing

The bidder's proposal must be signed with ink by the individual, by one or more members of the partnership, by one or more members or officers of each firm representing a joint venture, or by one or more officers of a corporation, or by an agent of the Contractor legally qualified and acceptable to the Ministry. If the proposal is made by an individual, his name and business address must be shown; by a partnership, the name and business address of each partnership member must be shown; as a joint venture, the name and business address of each member or officer of the firms represented by the joint venture must be shown; by a corporation, the name of the corporation and the business address of its corporate officials must be shown.

The proposal bid bond, if bid bond is tendered, shall be properly signed by the bidder and the surety.
2.6. Withdrawal Or Revision Of Proposals

A bidder may withdraw or revise a proposal after it has been deposited with the Ministry provided the request for such is received by the Ministry in writing or by telegram before the time set for opening proposals. No proposal can be withdrawn, modified, or corrected after the hour set for opening such proposals.

2.7. Public Opening Of Proposals

Proposals will be publicly opened and bid totals read aloud at the place, time, and date indicated on the "Notice to Contractors" advertisement. Bidders or their authorized agents are invited to be present.

2.8. Material Guarantee

The successful bidder may be required to furnish a complete statement of the origin, composition, and manufacture of any or all materials to be used in the construction of the work together with samples, which samples may be subjected to the tests provided for in these specifications to determine their quality and fitness for the work.

2.9. Bid Submission Manner:

Contractor shall submit his bids according to the form which is specified for that, to the ministry enclosing all the documents and information indicated in the announcement. All the required documents shall be original or an approved and authenticated copy.

Bid submission shall in accordance with the announcement in two separate envelopes placed inside a third wax sealed one. On the envelope contractor shall write contractor's name, competition name, competition subject, invitation number and date, and envelopes opening date.

The two envelopes include the following:
(1) The first one includes the financial proposal according to the approved tender form, which include total price of contract, unit prices of work items according to the BOQ attached with the invitation, and a table that includes analysis of price details.
(2) The second envelope is submitted when the invitation stipulates that, and it includes a technical report from the contractor in which he describes his plan for completion of the works, a list of the engineers, technicians, equipments and machines as required in the invitation announcement.

Contractor shall meet all the conditions indicated in the announcement and other documents approved in the kingdom, and the Ministry of Municipal and Rural affairs, which are indicated in the invitation.

Contractor shall be committed to his proposal for a period not less than three months or the period indicated in the announcement, whichever is longer. Also, he shall be committed to that tender after opening envelops, contract award, and before contract signing, till the end of the period stipulated in the conditions, specifications or announcement, or public works for and government purchases regulations, and manuals and instructions applied in the kingdom and by MOMRA Ministry of Municipal and Rural affairs.
All documents and sheets submitted in the tender shall be signed and approved by the contractor, and it is not permissible to incorporate any amendments in these.

Kingdom of Saudi Arabia Ministry of Municipal & Rural Affairs
Secretariat/Municipality/ Assembly

Tender Submission Form

H. E. ................................................................. God Blesses Him
Reference to competition No. ...... Dated ............ Announced by
......................... Concerning the works of
................................................................................ ,

We are pleased to submit our bid for executing the required works in accordance with the approved conditions & specifications, within the contract period stipulated in the competition documents, for an amount of SR ............... only ............... SR. We hereby enclose work items unit and total price table, and another table for the details of prices of each work item.

We, acknowledge that we have reviewed the competition documents, drawings, and the approved specifications for the works, the project site, and materials type and source. We accept awarding the contract to us according to the prices and period indicated in our proposal and the competition conditions, without any objection or claim or price increase, and that we shall commence work immediately after being handed over the site.

Official Address:
Mail Address:
Telephone No.:
FAX No:
Email:
Best Regards:
Bidder:

Name: ..........................................................................................

Title: ..........................................................................................

Signature: ..................................................................................

Stamp........................................................................................
2.10. References


MOT KSA;"General Specifications For Road And Bridge Construction"; November 1998.

MOMRA: Kingdom of Saudi Arabia Ministry of Municipal & Rural Affairs Deputy Ministry for Technical Affairs – Bridges Design Specifications (MA-100-D-V1/2 & V2/2) 2013.
SECTION 3. GENERAL RULES

3.1. Introduction
The general rules stipulated in this division are subject to the rules of public works form, regulations of government purchases & execution of its projects/works, and their executive bill and amendments at contract signing. The rules indicated in the public works form, regulations of government purchases provision and execution of its projects and works take priority in case there is contradiction between these and what is indicated in these general rules. Any matter, for which no stipulation has been indicated, is subject, in these general rules, to public works form, regulations of provision of government purchases and execution of its projects and works implemented at the time of contract signing.

3.2. Work Scope and Documents

3.2.1. Contract Purpose
The purpose of the contract is completion of the works listed in the BOQ Bill of Quantities, additional works and modifications which Contractor may intend to execute according to updated items, according to drawing specifications, general specification and professional standards. Contractor shall provide trained and qualified manpower, machines, equipments, technically acceptable materials, conducting measurements and testing, submission of technical reports and drawings, in addition to all requirements for carrying out the works and finishing these according to drawings and approved specifications within contract period or agreed extension period.

3.2.2. Contract Documents
Contract is composed of the following documents:
   a. Main contract document.
   b. Special conditions if any.
   c. General conditions.
   d. Special specifications if any.
   e. Drawings & diagrams.
   f. General specifications.
   g. BOQ & price rates.
   h. Award letter.

Contractor shall abide with contract documents with all their details and to deal with these as an integrated package which compliment, clarify and explain each other. He shall not exploit any mistake, ambiguity, or apparent shortage on the drawings or specifications and take it as a basis for claiming additional payments or lowering the quality of used materials or executed works. When Contractor notices such mistake, or ambiguity or shortage, he shall inform the Engineer who shall explain and clarify that and return to the agency which prepared specifications and drawings to enquire, when necessary.

When a difference or contradiction is encountered in the contract documents or in case of dispute, contract documents shall be handled on bases of the following:
1. When there is a contradiction or difference between rules of contract documents, the former document prevails over the subsequent one according to the order indicated at the beginning of this paragraph.
2. Measurements shown in figures are adopted and measurements on the basis of diagram scale are not adopted.
3. Adopted special work drawings are those provided by the Ministry or those submitted from the Contractor and approved from the Ministry or its representative, if any.
4. Standard drawings are not adopted.
5. Project special specifications or disputed work item are adopted, but general or complimentary specifications are not adopted.
6. Special specification stipulation is adopted when there is contradiction between it and standard drawings or special drawings.
7. In case there is a difference between dimensions shown on the drawings and those listed in the BOQ, dimensions shown on the drawings are adopted.
8. When there are no specifications for a certain item or article, reference is made to specifications applied for similar works and prevailing norms.
9. Contract text rules, contract general specifications, and regulations for tenders implemented in the kingdom, at contract signing have priority on rules and conditions indicated in these general specifications.
10. When there is a difference between the Arabic and an English version of the contract documents, the Arabic version shall be adopted for all contract documents, including general specifications and contract conditions, and if there is difference between the digits and the letters of the numbers the numbers with written letters is adopted. Specifications issued from SASO – Saudi Arabian Standards Organization, if any, shall be implemented for all materials and works, and shall take priority over other standard specifications, except otherwise special specifications stipulate for a more recent standard specification that achieves technical requirements even better.

3.2.3. Contract Language

Arabic is the approved language for interpreting and executing the contract. Both parties may write the contract or part of it by one of the foreign languages besides Arabic. In case where there is a contradiction between Arabic and foreign text, Arabic version will be adopted. Arabic is adopted in general specifications, and it is possible that the two parties may use an English copy, however, the Arabic version is the one which is considered when there is contradiction between the two versions.

Correspondence between the two parties shall be in Arabic, and Contractor may use a foreign language, providing that he submits with it an approved translated copy in Arabic which will be considered as the basis in case of contradiction.

3.2.4. Additional Drawings

When additional drawings are prepared and submitted, those additional drawings aim at showing contract work details and not changing it. Those drawings shall have the same rating as to contract control and execution requirements.

3.2.5. Special Work

Special works are those parts of work included in the contract but not sufficiently described in the general specifications or complimentary specifications, and for which
special specifications were prepared. Those works shall be considered as part of the contract, all contract requirements are applicable to them and their special specifications are considered as part of the contract documents.

3.2.6. Non-Estimated Items

The Ministry when necessary and without violating the law in case it expects appearance of some work items which should be executed to complete the project properly, while it is not possible to estimate their quantities; has the right to prepare prices for those works on the basis of prevalent prices at the time of announcement. Those prices become the contractual rate for such works, and the quantities of those works are estimated during execution.

3.2.7. Addition, Omission, and Modification in Work Items

The Ministry has the right, at any time during contract period, to make any changes in the quantities of work items whether through adding or reducing. Any omission or addition or modification in contract work items, shall be made on the basis of the legal documents approved in the contract, particularly Article 43 of public works form and/or government purchases regulations and its executive bill or legal documents of contract. At all times, it is not allowable for the Contractor to take any measures or actions arising from the addition or omission or modification without obtaining an approved written acceptance from the Ministry or its representative within the authorization delegated to him.

Changes in the quantities of work items shall not lead to a change in contract works or sites or an increase in contract quantities of more than the rates specified in the public works form, plus 10% or minus 20% of contract total value. Contract value shall be amended with the addition or omission accordingly.

3.2.8. Introduction of New Items to the Project

When it is necessary to introduce works not clearly or inclusively included in the contract, that shall be done on the basis of the public works form, government purchases and its contracts regulations, and approved legal principles. Those works shall be so necessary that their non-execution shall prevent completion of other items and works in the project, or prevent or reduce getting use from the project or limit its technical quality.

Introduction of any new items shall be made according to Article 43 & 44 of the public works form and other legal documents approved in the contract. Also, introduction of new item shall be made on the basis of a technical report prepared by the specialized technical agency including the technical justifications for the introduction, specifications and quantities of the works for which new items are proposed. Also, it shall include a confidential report for the costs of carrying out introduced items; then Contractor is asked to submit his prices for carrying out those items and discuss those prices with him. These prices shall be in compliance with prevalent prices for such works at the time of their introduction.

It is allowable to commence execution of any introduced works before completion of regulatory procedures and the introduction approval. The introduction shall not result in an increase in contract value by more than the maximum allowable increase rates.
3.2.9. Modification Claims and Disputes

When Contractor considers that he has a right to claim additional costs against work or item that has not been included in the contract clearly, or has not been assigned as an additional work by the Ministry, he shall inform the Engineer in writing about his intention to submit a claim before submitting any claim for additional compensation.

Engineer shall review the request, calculate the quantities, evaluate the cost, and prepare his report on this. These procedures from the Engineer shall not be considered as an acceptance for the right of Contractor on compensation.

Decision on the Contractor's right shall be decided by a committee formed from the Ministry to study the request, Engineer's report, and review contract documents; then submit a report to the authorized agency in the Ministry. The Ministry takes its decision on the basis of the submitted reports and legal documents.

When disputes or conflicts appear during contract execution, they shall be handled by a committee formed from representatives of the Ministry, the Engineer, and the Contractor. Its task is to try to reach a mutual rapprochement. When this committee fails in achieving understanding within 28 days, the dispute is forwarded to the grievances board in KSA, which study the dispute and take decision. The decision from the grievances board is obligatory to all parties.

3.2.10. Removal and Disposal of Structures and Obstructions

Contractor shall remove structures, obstructions and materials which interrupt project works or its permanent or temporary structures, transporting removed products to approved sites. Removal and disposal works shall be on the Contractor's account and considered incurred by other work items under construction; except otherwise mentioned in a separate item of BOQ.

3.2.11. Power & Water Supply

Contractor, on his own account, shall make the required arrangements to provide power and water supply required for executing the project works. It is strictly prohibited to supply power and water from public networks without prior coordination with the concerned authorities.

3.2.12. Coordination between Works

On the basis of Article 24 of the public works form, Contractor shall provide the opportunity to other Contractors and he shall inspect site, verify information on projects being executed by other Contractors which may contradict with works of his contract. Also, he shall coordinate with those Contractors and project owners, and prepare his rates and work plan accordingly. That shall not taken as pretext for amending prices or modifying completion period after assignment.

3.2.13. Site Evacuation and Cleaning After Work Completion

Contractor shall, in lieu of Article 25 of public works contract form & other legal documents approved in the original contract, and immediately after completion of the project works and before submission of work handing over request, evacuate all the project sites from all works and temporary structures, machines, equipments, and wastes; and he shall clear those sites. Also, he shall evacuate, arrange, and clean all extraction sites and stockpiling yards of materials used for the project.
Contractor shall obtain the Engineer's acceptance for evacuation and cleaning operations before handing over the project works, and Contractor shall not be paid any additional costs against that but shall be considered as charged on all contract items.

3.2.14. Construction & Execution Record Books

Contractor, on his own account, shall open a record for work phases in the project in which he records daily work sites and phases, layers and/or works under progress, list of equipments and machines operating in the project, attendance of Contractor's technical teams, proposed materials and summary of testing and measuring results, while keeping a copy of this with the supervising Engineer. This record shall be approved and signed from the Engineer. When the Engineer requires, Contractor should take photos structures and distinct works.

Contractor shall submit periodical reports on work progress in completing the project together with a summary of the results obtained and the work plan for the next phases of the project; including difficulties and problems he is encountering during execution.

3.2.15. Workshop Drawings

Contractor shall submit workshop drawings required by the Engineer. Those drawings show all the details related to various work items which are not shown on the standard drawings provided from the Ministry. Also, he shall make the modifications and changes required by the Engineer on the standard drawings delivered to him with contract documents, before he commences execution of those items by a period not less than 15 days. Those drawings shall include all the details required for the execution of work items and traffic control plans at work site and temporary detours if any. Contractor has no right to commence relevant works before he obtains the Engineer's acceptance for the workshop drawings, modifications and additions.

3.3. Legal Relations and Responsibility Towards The Public

3.3.1. Law Abidance

Contractor shall abide completely with the existing laws and regulations in the KSA and shall be aware of those regulations and laws; since his ignorance of those regulations and laws does not release him from any responsibility arising from his violation, or the violation of any one of his employees or his subcontractors, to existing regulations and laws.

3.3.2. Authorizations, Licenses, and Charges

Before starting work, Contractor shall obtain all authorizations and acceptances required for work completion from all the concerned governmental and private authorities and he shall pay all charges and expenses arising from this. He has no right to claim any additional payments for that.

3.3.3. Patent Right and Ownership

Contractor shall adhere to patent rights and ownership directives. He shall protect and compensate the Ministry for any claims and actions arising or caused by violation of any right or privilege or design or commercial brand or name or other registered rights concerning any equipments, or machines, or materials used in carrying out the works or temporary works or any of those, in compliance with Article 21 of the public
works contract form. Contractor remains responsible throughout work period and after it for any violation related to patent right and ownership.

3.3.4. Royalties

Contractor shall obtain the special acceptances for material extraction, and he bears all royalties arising from that or any other royalties he incur, and no amounts shall be paid for him against that but shall be considered as charged on work items.

3.3.5. Relations between Contractor and His Employees and Employees of His Subcontractor

Contractor shall implement all the laws and regulations existing in KSA regarding his relations with his employees and employees of his subcontractor. He shall incur all expenses and charges arising from that. He is responsible alone for all compensations and expenses resulting from harm to any one of his employees or his subcontractor employees, and the Ministry is not responsible for any consequences arising from that.

3.3.6. Insurance

Contractor shall adhere to all stipulated insurance procedures against any losses or damages for which Contractor are considered as responsible according to contract and approved legal documents. Insurance shall be made in accordance with Article 12/5 of public works contract form and other legal documents approved in the original contract.

Contractor, before he starts work, shall submit a copy from the insurance policy/policies approved from the insurance company. Also, all insurance contracts shall be valid throughout execution periods and those policies shall stipulate that the insurance company undertakes to inform the Ministry about its intentions for nullifying the insurance before taking such action by sufficient period not less than 15 days.

3.3.7. Monuments and Fossils

Contractor shall adhere to all laws, regulations and instructions related to dealing with archeological buildings and sites and with all materials, pieces, fossils, and precious materials he may encounter during work execution. Those materials should be treated according to Article 20 of public works contract form.

Contractor shall report such materials immediately after discovering them and within a period not more than 24 hours. He shall maintain those items and protect them from damage or any harm. He shall prevent their transfer by his employees or any other person, and he shall stop work at those areas until he receives written instructions from the Engineer and concerned authorities.

3.3.8. Alcoholic Drinks, Drugs, Weapons, Ammunition, and Keeping Order

Contractor shall adhere to regulations and laws concerning prevention of importing, producing, selling or using or transporting alcoholic and drug materials by him or by his employees, and he shall abide with regulations and laws concerning weapons, ammunition and all law/order regulations.

3.3.9. Property Preservation

Contractor shall prepare work plan and work execution in such a way which does not lead to any damage on adjacent property and structures. Before he commences execution, Contractor shall identify all the structures, public utilities and any other
elements which lie within work boundaries or which may be affected by those works, then he shall prepare a technical report in coordination with all the concerned parties, and obtain approval for the solutions for each of them.

Contractor shall abide by all approved solutions and shall not inflict any damages on structures, public utilities and identified elements. When he encounters during work any of those undiscovered elements during preparation of the report, he shall stop work and inform the Engineer and coordinate with the concerned authorities to approve the suitable solution. Contractor bears the whole responsibility for damages that may be inflicted on structures, public utilities and elements arising from movement of his equipments or any of his activities. He shall repair those damages according to the requirements of the concerned authorities, and he has no right to claim for any additional cost against such repairs.

3.3.10. Contractor's Responsibility for Work

Contractor remains responsible for all project works up to the end of the guarantee period stipulated in the contract and preparation of final handing over minutes. Throughout this period, Contractor shall carry out all maintenance and repair works which the works may need. He shall carry out all repair works required by the preliminary & final handing over committee, and he has no right to claim any additional costs for that.

Exceptions are made for damages arising from special risks, overcoming force or third party which are reasons outside the scope of Contractor's control and are not expected. These are not arising from a mistake or shortage or negligence from the Contractor's side, and Contractor in this case does not incur repair costs and compensation. He shall inform the Ministry about any damages arising from such conditions within a period not more than 10 days from the date of damage. In such case Article 55, 56 of public works contract form is implemented.

3.3.11. Personal Responsibility of Government Officials

The Engineer or any of his authorized assistants do not bear any responsibility for practicing the powers and authorizations granted to them according to contract for executing its items; whether individually or in his capacity as an employee of the Ministry, since he is carrying out this work as a representative and an agent of the Ministry.

3.3.12. Preservation of Environment

Contractor shall adhere to all the environmental and health standards approved from the concerned authorities during all phases of work. Before commencing production and execution works, he shall obtain the approved environmental standards, and shall study, understand them, and apply them.

Contractor shall take all the measures and arrangements required for reducing contamination arising from any of his activities during executing contract works including reduction of noise levels and dust propagation and control of vibration rates. He shall calibrate all his machines, equipments, asphalt or concrete mixes production plants, production and storage centers of different materials and to make arrangements of contamination level control to remain within approved allowable levels from the authorities concerned with the environment.
3.3.13. Dangerous Wastes

Contractor shall adhere to all environmental and health standards approved by the concerned authorities when encountering or using materials or wastes considered as dangerous to public health and environment. Immediately after discovering any materials or wastes or spilling of any hazardous materials, which he needs for work, Contractor shall coordinate with health and environment authorities to approve the procedures he shall apply. Also, he shall review all publications regarding handling of dangerous materials used in his work and he undertakes to deal with such materials according to the instructions of health authorities and manufacturer's recommendations.

When it is necessary, Contractor shall provide all protection requirements and apply all its arrangements. He shall train his employees who deal with such materials on methods of their usage and handling, and training them on safety procedures, first aid and to require from them to use all required safety devices. Contractor bears alone all the results arising from his failure in this regard.

3.3.14. Using Explosives

Explosive shall be used in carrying out the works only in very critical situations and when there is no other way for executing the work, after the Ministry acceptance. Explosives shall be used according to Article 49 of public works contract form. Contractor shall obtain all the required licenses and approvals from the concerned authorities regarding the use of explosive materials in executing the project works.

Contractor shall obtain, transport, store, and use explosives according to the instructions and written acceptances from the concerned authorities, and he shall keep the records of quantities of materials supplied to the project and the used quantities.

In all cases, Contractor shall prove to the Ministry his previous experience in blasting works or sign a contract with a qualified agency to carry out these works. He shall obtain the acceptance of the Ministry and concerned authorities for that contract.

Contractor bears alone any consequences or damages that arise from his failure in obtaining the acceptances or licenses or for not abiding with the regulations and laws related to using explosives or using these improperly. Also, he shall be responsible for any harm on life and property including project structures arising from use of explosives.

3.3.15. Losses on Persons and Properties

Contractor shall preserve all public and private properties and he bears losses and damages on persons and properties arising from any action or failure or negligence or misbehavior during construction and maintenance of project works. Also, when that is due to a defect in the materials and used construction methods. Damages shall be estimated on the basis of Article 18 of public works contract form, legal documents and other contract documents.

3.3.16. Traffic Control at Work Site

All traffic control works shall be made at work sites according to traffic control at work site manual issued from the Ministry of municipal and rural affairs, under the supervision of the central committee for projects coordination, special specifications these general specifications and traffic regulations. Costs of all traffic control works are considered as charged on contract items, except otherwise stipulate special specifications and BOQ for separate items for those works.
Contractor, before he starts construction works, shall prepare the traffic control plan during execution and shall obtain the acceptance of the Engineer and concerned authorities for it. In all cases, the traffic control plan shall provide continuity of public and pedestrian traffic and access to all buildings and adjacent structures. Also, the plan shall result in the least possible interruption for traffic movement. Contractor shall carry out all the necessary works on the basis of that plan including placing signals, signs, direction signs, barriers, construction of temporary detours and walkways and their maintenance. In addition, he shall remove all the temporary elements and equipments and return their sites to their original state after completion of the project works.

Contractor has no right to commence construction works before he performs traffic control procedures and works according to the approved plan and handing over those works to the Engineer. Also, Contractor bears all the financial and legal consequences which may arise from his failure in traffic control procedures.

3.3.17. Safety Precautions at Project Site

Contractor shall make all arrangements and execute all the works necessary for the safety of employees, pedestrians, neighbors, buildings, and adjacent structures from any damage due to Contractor works and he shall support excavation sides fence excavation and trenches when required.

In addition, he shall provide protection means such as safety barriers, protective hats hoods and gloves and he shall instruct his employees to use them and provide them with the first aid supplies together with firefighting systems which should be placed in a clear location. Contractor shall bare full responsibility for any damages arising from his failure in providing safety arrangements and applying them.

3.3.18. Guiding and Lighting

According to Article 17 of the public works contract form, Contractor shall execute lighting, fencing, and guiding works for all work sites including warning lighting at excavation and trenches sites. Also, he shall provide guiding at all the sites of his machines, equipments and material stores.

3.4. Supervision on The Works

Supervision works shall be performed according to the latest edition of Projects Execution Supervision Procedures Manual issued by the Ministry of Municipal & Rural Affairs in KSA, and the Ministry appoints, the supervision staff, their duties and authorizations.

3.4.1. Supervision Staff

The produced and used materials and executed works shall be inspected, tested and accepted from the approved authority assigned from by the Ministry to supervise the project. Contractor shall facilitate access to the Ministry representative to all work and production sites, material stores, sampling and measuring areas.

3.4.2. Supervision Staff Duties

The task of the supervision staff is concerned with monitoring, inspecting, testing, and measuring project materials and works Also, inspection of Contractor's equipments and machines and to verify that Contractor has carried out the work by using the
materials, work methods, dimensions, and levels shown on the drawings, special and complimentary specifications, general specifications, and other contract documents.

Supervision staff performs the following:

1- Audit all reports, work plan, time schedules, and design job mixes submitted by the Contractor and to provide the necessary comments, if any, or approve them.

2- Assist Contractor to understand and conceive drawings and specifications for executing project works with the required technical standard.

3- Review results of measurements, material and work testing, and verify Contractor's implementation of approved drawings and specifications.

4- Audit project daily record books and audit all shop drawings and as-built drawings prepared by the Contractor and approve these.

5- Audit executed work quantities and approves current payments and final payment.

6- Keep copies all of specifications, drawings, contract documents, project records and reports.

3.4.3. Supervision Staff Authorities

The authorities of the supervision staff are determined on the basis of the latest edition of the projects execution supervision manual issued from the Ministry of municipal and rural affairs and similar manuals approved from the Ministry. The Engineer is empowered to:

Stop work completely or partially when he notices Contractor's failure in abiding with approved drawings, work mixes and methods; and he may require removal of materials or works or machines or equipments which he considers as unacceptable and replace them with others technically accepted on the Contractor's account.

Instruct for necessary modifications in applied work methods for the purpose of obtaining work compliant with specifications and drawings within allowable tolerances shown on the approved drawings specifications.

Stop work due to climatic conditions or other important reasons decided by the Ministry.

Monitor work attendance and efficiency of the Contractor's technical teams, his machines, and equipments and to require replacement of those who lack the efficiency required for executing project works.

3.4.4. Supervision Staff Facilities

Contractor shall, when contract documents require that, provide and prepare supervision staff facilities such as offices and their accessories; transportation means to enable the supervision staff to carry out his duties, according to contract. Supervision staff facilities shall be composed of Engineer offices which are provided with computer, printer, and telephone/fax line, computer systems, all according to contract documents.

The facilities shall be compliant in all aspects with government and municipal regulations and instructions concerning abidance with medical principals and separation between facilities and other details indicated in contract documents.
3.4.5. Laboratory, Measuring and Testing Systems and Equipments

Contractor shall provide at site, and on his own account without the Ministry being incurred additional costs, all the systems and equipments required for conducting work measuring, sampling and sample storing/testing which include at least the following systems and equipments:

3.4.5.1. Measuring Equipments

It must include surveying equipment that measure the distances and angels and elevations with the required accuracy for the works, with all its accessories, these equipment should be in good technical case and they have to be calibrated from specialized team, the Contractor shall provide leveling steal rod with dimensions as shown in the specifications.

3.4.5.2. Sampling, Samples Storing and Testing Systems and Equipments

Contractor shall provide at site all the systems and equipments required for materials and works sampling and testing. Also, the required molds for blending mix samples and equipments of storing them according to approved standard specifications for the purpose of taking and blending samples and testing them. Contractor can, with the acceptance of the Ministry, contract an independent laboratory approved from the Ministry, to carry out the sampling, preparing, and testing processes, and in such case the laboratory technicians shall be available at all times of sampling.

3.4.6. Client Commitments

Client shall provide all the facilities required from him for executing project works in compliance with approved drawings and specifications. Some of those facilities are addressing letters to all other authorities for facilitating Contractor's task and assistance in coordination concerning public utility works, providing necessary services for carrying out project works, speed up approval of sudden modifications on drawings and/or specifications, and quantities. Also, speed up replying all the enquiries and paying all Contractor and supervision staff dues.

3.5. Execution Conditions and Work Progress:

3.5.1. Work Site Inspection

Before submission of his bid, Contractor shall inspect the work site and study all details, obstructions, structures and any obstacles which may encounter during execution. He shall include in his proposal all his comments, suggestions, and reservations and any comments, submitted by the Contractor after submission of his bid, on amendment of work item prices or increasing contract period or reducing work quality, are not considered. All the information indicated in the drawings and special specifications are considered as inferential primary information and Contractor shall prepare his prices and work plan according to the information gathered by him on work site and availability of construction materials and supplies.

3.5.2. Work Site Handing in

The Engineer shall hand in work site to Contractor, which means all lands and locations to be used for executing contract works, according to minutes signed by Contractor or his authorized representative and the Engineer. Work site handing in can be made in the form of sections which provide the possibility of project work
completion according to the contractual period and construction time schedule. The site shall be free from all work obstructions of which removal or transfer are not part of work scope.

Work site handing in procedures shall be conducted after contract signing by following the steps indicated in the latest edition available at the time of contract signing of Road Project Supervision Procedures Manual issued from the Ministry of Municipal and Rural affairs. The separating period between contract signing date and date of work site handing in shall not exceed 30 days, except otherwise the delay was due to substantive reasons decided by the Ministry or otherwise stipulate contract.

In case there are obstructions which prevent site handing in, the procedures stipulated in the Projects Execution Supervision Procedures Manual shall be completed.

3.5.3. Contractor Commitments

Contractor shall provide qualified engineers, technicians, skilled/unskilled labor force, for carrying out contract works. Also, he shall provide all materials which are compatible with approved specifications, machines and equipments which are capable of executing the works according to the drawings and approved specification within the specified periods and approved time schedules.

The Engineer, when he notices delay from the Contractor's side in work execution, has the right to instruct him to work additional hours without having the right to claim any additional costs arising from that.

3.5.4. Work Site Planning

Immediately after work site handing over and pilot survey points, Contractor shall carry out the necessary survey works for determining road centerline, and all elements and structures attached to it. And he shall determine work boundaries by the method accepted from the Engineer, and establish survey link points & protecting them from removal or damage for any reason. Contractor has no right to commence work before auditing survey works and approve them from the Engineer.

3.5.5. Compliance With drawings and Specifications

Contractor shall provide all materials and execute all works according to the lines, levels, cross sections, dimensions, and material requirements shown on the drawings or mentioned in the approved specifications within allowable tolerance limits. Contractor shall remove all works and materials which are not in compliance with the drawings and approved specifications, shall replace them with other acceptable materials/works on his own account; and he has no right to claim any additional costs for that.

3.5.6. Coordination with Public Utilities & Structures Authorities

Contractor shall, with the help of the Ministry and before commencing work execution, coordinate with public utilities or structures owners. This shall be done to determine utilities and structures lying within project boundaries or those which may be affected by the project works during construction or operation. Coordination with those authorities to approve the solutions related to those facilities and/or structures whether through reconstruction, or modification or transference or removal; and to approve the work plan and work phases.

Organization and recording of coordination works shall be done according to official minutes approved from all parties the Ministry, structure and public utilities
owners, Contractor; and these minutes, solutions and plans are added to the contract documents.

3.5.7. Signs

Contractor shall, within 60 days from contract signing or 2 weeks from date of site handing over whichever is closer, place two signs at two prominent locations at the beginning and end of the project on which is written project name, project owner, Contractor name, project period, expected date of completion, both in Arabic and English.

Dimensions and sites of the two signs shall be determined through agreement with the Engineer and he shall maintain the signs and clean them throughout project period. Contractor shall not be paid any amounts for that.

3.5.8. Contractor's Technical Staff

Contractor shall provide sufficient number of engineers, inspectors, surveyors, and technicians according to project execution requirements. Contractor's technical staff shall be suitable for project works as to qualification and experience. Contractor, before commencement of the works, shall submit to the Engineer a list containing names, qualifications and experience of his proposed technical staff for approval, and he has no right to change any of the technical staff after being approved before obtaining a written acceptance from the Engineer.

The Engineer has the right to reject or require change any one of the technical staff when he notices his lack of efficiency and abidance with work conditions or due to his bad conduct. Contractor shall replace him with another more qualified and capable of carrying out the work according to drawings and approved specifications. Also, Contractor shall name the project manager and his assistants and obtain Engineer's acceptance for this.

3.5.9. Penalty for Absence of Contractor Technical Staff

The Engineer has the right to impose absence penalties on one or some of the members of Contractor technical team according to the contract signed with the Contractor, requirements of the nature of the work and assignments of the absent staff. Deduction for each absence day is made according to contract stipulations. The Engineer has the right to stop Contractor from work temporarily if he noticed that existing Contractor's staff is not capable of executing the work in compliance with approved specifications, and Contractor has no right to claim any compensation or additional periods due to that.

3.5.10. Work Program and Time Schedule

Before he starts construction works, Contractor shall submit to the Engineer the work plan and time schedule for completion of all items and phases of work. The proposed completion period shall be compliant with contract period. The time schedule shall be submitted in the form of a graphic chart based on critical rout that show work dates and phases and work sites. Also, it shall consider overlapping between various item works, also, it shall show machines, equipments, labor and materials required at each phase.

Contractor shall consider the necessity for coordination with other Contractors who are, during project works, carrying out works at his work sites, also coordination shall
be made between works such that obstructions arising from work overlapping for any of the Contractors shall be as few as possible.

3.5.11. Construction Equipments

Before starting construction works, Contractor shall submit to the Engineer a list of all machines and equipments he proposes for use to carry out project works. These equipments shall be technically capable of carrying out works in accordance with specifications and drawings within the contract period.

Contractor is not allowed to transfer any of the equipments and machines for work in other projects or sites or replace any equipments or machines before obtaining the Engineer's acceptance. Also, Contractor shall keep equipments and machines in an operational condition and shall carry out the necessary maintenance and repair works.

The Engineer has the right to reject or require replacement any of the equipments and machines when he notices its repeated failures or incapability to execute the works according to approved specifications.

3.5.12. Pre-Construction Meeting

Immediately after contract awarding, work site handing over, submission of work plan and time schedule, and list of machines and equipments, the Engineer may call for a meeting attended by the Engineer and Contractor or their representatives. In this meeting all details concerning the project and the Contractor's proposed work plan shall be discussed.

Meetings shall be held before executing some work items for which a separate detail plan shall be prepared, such as blasting works. Also, mutual meetings shall be held with the owners of structures and public utilities lying within or adjacent to work site which may be affected by the project works for the purpose of discussing and approving solutions related to those utilities and structures.

3.5.13. Subcontracts

Contractor can subcontract for executing some contract work items and that shall be done according to Article 4 of public works contract form and other legal documents approved in the original contract. In all cases, Contractor shall submit to the Engineer a full report on the subcontractor with whom he intends to make the agreement, that includes name of company or Contractor, his qualifications and previous experience, and the works he is intended to carry out. The sub-Contractor is not allowed to commence work before obtaining the Engineer's acceptance.

The Engineer's acceptance does not release Contractor from his full responsibility for executing the contract according to approved drawings and specifications. Contractor alone bears the responsibility for any failure or violation that occur from the subcontractor or his employees on contract execution or site.

3.5.14. Night Work

The Ministry may allow Contractor to carry out some works at night when the need calls for executing works within a short period or when work execution requires relatively moderate temperatures or for reasons decided by the Ministry. In all cases the Contractor shall, when the Ministry allows him to work at night, prepare a detailed plan together with specific time schedule four night working hours, coordination with concerned authorities, and provision of the supervision staff during night work.
Execution Conditions and Work Progress:

Section 3: General Rules

Contractor shall place warning signs and provide sufficient lighting to ensure safety conditions for public traffic movement and neighborhood. Lighting shall be sufficient enough for executing the works accurately and according to approved specifications. Also, Contractor shall take all the required measures to lessen noise level to the neighborhood due to his works.

3.5.15. Unusual Traffic

Contractor shall adhere to allowable vehicle dimensions and loads when driving on public roads and their elements such as bridges and tunnels. He shall apply all the required efforts to ensure that cars and machines he uses do not exceed those limits. He bears the full responsibility for not adhering to those allowed limits.

When Contractor needs to transfer some machines and equipments which do not comply with dimensions and loads allowed in the kingdom, he shall prepare a technical report including dimensions, values, and axial/total loads transferred on the road. Also, dimensions of the transportation means he intends to use and selection of a certain route.

In addition, he shall submit a technical report prepared by a specialized agency showing that the load passing according to the proposed route shall not result in any damage on the road and structures according to the proposed route and indicates the required works for temporary supports for bridges, culverts and other structures and construction of temporary detours when needed.

Contractor has no right to transport before obtaining the Ministry's acceptance of the report, study and completion of all the works related to load passing.

3.5.16. Temporary Work Halting

When the Ministry decides the necessity for halting work in executing the works or part of them temporarily, in accordance with Article 32 of the public works contract form or other contract legal approved documents; that shall be done according to the procedures and conditions specified in Projects Execution Supervision Procedures Manual issued by the Ministry Of Municipal & Rural Affairs and contract approved legal stipulations.

3.5.17. Defects and Failure

Consultant has the right, at any time during work execution, to require from the Contractor to remove works, transport technically unacceptable materials and replace these with other technically acceptable and compliant with specifications, drawings and contract documents. Contractor shall carry out the Engineer's instructions immediately on his own account and he has no right to claim any additional cost for that.

Contractor shall preserve the executed works throughout construction period and guarantee period. Also, he shall carry out all the required repairs for any defect that may appear on his own account without having the right to claim any additional costs for that.

The Ministry has the right, when it notices that the Contractor is delaying or failing in carrying out protection and maintenance works required from him, to assign a third party for carrying out those works and deduct costs resulting form this from Contractor's dues with the Ministry or from his insurance or may be collected from him legally when his dues are not sufficient for covering those costs.
3.5.18. Work Withdrawal

When the Ministry decides to withdraw contract works, for one of the reasons stipulated in Article 53 of public works contract form or other legal documents approved in the contract, procedures of work withdrawal shall be done according to public works contract form or those legal documents. Also, when resorting to work withdrawal, the Engineer shall, in the presence of Contractor or his representative, carry out the following:

1. Prepare a full report on the project including quantities of completed and handed over works, inspection of incomplete works and handing them over, measuring their quantities if acceptable and adding them to the completed works. Also, an inventory shall be made for the remaining works which should be completed to accomplish the project and their locations.

2. Inventory, inspection, and testing of quantities actually supplied for use in the project. The Ministry has the right to accept these as raw materials in case they comply with specifications required for uncompleted works within the required quantities for completing the works.

3. To prevent Contractor from withdrawing any of the Contractor's or subcontractors technically accepted materials, equipments, and machines to be held for the benefit of the project.

No dues will be paid to the Contractor before completing the works by another Contractor, handover the works, expiry of the contract guarantee period, and verification of that no financial obligations or any other obligations are due to the Ministry on Contractor which may prevent that.

3.5.19. Assigning Withdrawn Works to another Contractor

Assignment of withdrawn works according to the previous paragraph shall be made according to Article 54 of public works contract form and other legal documents approved in the contract. And the Ministry has the right to hold machines, equipments, and materials. Also, can hold Contractor's financial dues with the Ministry, until withdrawn works are completed, financial accounts finished, and required actions for covering execution costs are taken according to stipulations and legal standards.

3.5.20. Contract Period

Contract period is the period specified in the contract. Contractor shall prepare his work plan and work time schedule, provision of sufficient number of equipments and machines, and labor so that he may be able to complete the project within the specified period.

The date of site handing over is considered as the actual date for starting works and work site shall be handed in according to an official minutes signed from the Contractor and supervising engineer from the Ministry. The contract period is considered the complete period including official holidays.

Contractor is allowed to carry out work only in official working days, and when the need calls for work in holidays he shall obtain the Ministry’s acceptance, providing that arrangements shall be made for supervision on work execution.

The Ministry can extend the contract period according to Article 9-b of the government purchases and execution of its projects/works regulations and the regulations and legal stipulations approved in the contract, in case the required conditions for that prevail, such as assigning the Contractor execution of additional works which cannot be completed within contract period.
Also, the Ministry may grant the Contractor an additional period if he has been delayed for reasons outside his power or when he has been stopped from work temporarily by the Ministry for a certain period, providing that he submits a request to the Ministry, before contract end, including a justification for the delay in which he indicates delay reasons and dates in which he was compelled to stop work for insurmountable reasons attached with reports and official correspondence which confirm this. Decision on the request is taken by a special committee formed for this purpose at the Ministry.

3.5.21. Delay Penalty

In case Contractor delayed in completing the contract works and handing over at the specified date without justifying the delay period, or the Ministry has not decided that there is a reason for withdrawing the work, Contractor shall undertake to complete execution. In such case the delay penalties are calculated according to Article 39 and supervision costs during delay period according to Article 40 of the public works contract form and contract approved legal documents.

The delay penalty is calculated according to the following:

a. A penalty for the first part of the delay period in the rate of 1/4 the daily cost average for each delay day until the greater of the two periods amounts to 15 days or 5% of the contract period.

b. A penalty on the second part of the delay period in the rate of 1/2 the average daily cost for each delay day until the two parts amount to more than 30 days or 10% of the contract period, whichever is greater.

c. A penalty on the third part of the delay period in the rate of the average daily cost for each next delay day for the greatest of the two periods indicated in paragraph b.

It is not allowed for the penalties imposed to exceed 10% of the contract value. But if the Ministry surmised that the delayed part does not hinder getting use from the work at the time specified for its completion, or does not cause confusion in using any other facility, and does not adversely affect what has been completed of the work itself, total penalty shall not exceed 10% of the delayed works value.

Contractor, in addition to the stipulated delay penalty, incurs the charges of the project supervising penalty during the period in which the Contractor is subjected to the penalty, and those charges are calculated on the basis of the supervisor's contract whether it is a periodical amount or a percentage from contract value.

But if supervision was against lump sum amount or if it was performed from a governmental authority, supervising penalty is equal to the delay period percentage from contract period multiplied by the contract value, and calculated as follows:

\[
\text{Supervisor Penalty} = \frac{\text{Delay period}}{\text{contract period}} \times \frac{1}{100} \times \text{contract value}
\]

3.5.22. As-Built Drawings:

Contractor shall prepare as-built drawings in such a way that reflects actually completed works. They shall show lines and sites of all public utilities and structures lying within work boundaries. They shall be prepared with the suitable scale accepted and approved by the Engineer. Contractor shall submit three copies of as-built drawings approved from the Engineer to the Ministry at completion of the project works and before the preliminary handing over.
3.5.23. Ending Contractor's Responsibility:

Contractor remains responsible for all executed works and he shall carry out all protection and maintenance works throughout work guarantee period stipulated in the contract. Contractor is not released from the responsibility until the final handing over minutes are prepared, approved and delivered to the Contractor.

3.6. Control and Acceptance of Materials and Works

3.6.1. Materials and Works Control Procedures

Materials & works shall be controlled through quality control and assurance procedures shown on the drawings, special specifications, general specifications, complimentary specifications, and other approved contract documents.

Quality control procedures shall be performed by the Contractor through sampling, measurements, testing, and result analysis for all the properties which are required to be achieved and in the rates shown on the drawings and special specifications or in the divisions/sections dealing with quality evaluation of the works, of these general specifications.

In addition, Contractor shall draw quality maps of critical properties by using statistical technical methods. Those maps shall be conducted in the form of graphic charts showing the properties they represent and numbers of tests and measurements, while showing and highlighting target value line and allowable tolerance limits. Contractor shall provide the Engineer immediately with results of all the tests, measurements, and quality control charts.

Quality assurance procedures are conducted by the Ministry by verifying that Contractor has executed quality control procedures by the proper method. The Ministry carries out this either through direct supervision on application of quality control procedures or by performing quality assurance procedures in an independent neutral way on representative samples in adequate number, to judge the execution standard and decide about accepting or rejecting executed work. This is done according to the principles detailed in special specifications, other contract documents, and division 17 of General Specifications of Urban Roads Construction, except otherwise specify special specification or other contract documents.

The Ministry has the right to review Contractor's quality control records and comparing them statistically with the results it obtains through the method it specifies for quality assurance. Also, it has the right to inspect Contractor's laboratory, equipments, technical staff, investigation, testing, and execution methods he applies, to ensure efficiency of his technical staff and suitability of the equipments for the work being executed. Also, compatibility of investigation, testing and execution methods with approved methods.

Sampling shall be done according to the random method and those samples shall be representative to the material or work to be verified for compliance with requirements. Sampling and samples storing, preparation, and testing shall be according to the methods indicated in the standard specifications issued by SASO, if any, or by other international agencies such as ASTM or AASHTO, all according to contract approved specifications.
3.6.2. Material Sources

Before commencing supplying materials, Contractor shall submit to the Engineer a report including material sources, source guarantee certificate, results of tests on representative samples of materials which show their compliance with the approved specifications, and he has no right, by any means, to commence material supply before obtaining the Engineer's acceptance of the sources and materials.

Engineer's acceptance for materials and source does not release Contractor from his responsibility for achieving the requirements stipulated in the specifications and shown on approved drawings during the whole construction period. He shall, on his own account, transport all materials the sources of which has already been accepted and shall remove all the materials found to be, through testing results, not compatible with approved specifications. These shall be replaced with other materials and works technically acceptable, and he has no right to claim any additional costs arising from that.

3.6.3. Material Transportation and Storing

Contractor shall store materials at the sites approved from the Engineer by using the methods and equipments/machines which do not lead to change in the properties of stored materials. It is not allowed to use public squares inside urban areas for storing materials before obtaining written acceptance from the owners and the Engineer. He shall take all the required measures for protecting neighboring property from damage or noise or pollution as a result of this and he shall apply all applied standard particularly those dealing with lessening dust propagation.

Contractor shall transport earth materials, aggregate materials, asphalt and concrete materials and mixes, with covered transport means which prevent material scattering and consequently cause contamination to the environment and the streets they pass through. These means of transportation shall be organized and their routes chosen in such a way that cause minimum possible interruption to the traffic movement.

Contractor shall transport and store explosive materials according to the instructions and rules implemented by the specialized authorities outside residential areas and populated areas away from populated buildings. The distance between those stores, structures and mentioned areas shall not be less than 300 m.

Contractor shall provide strict guarding for those stores and shall keep records which show quantities of explosives received, explosives and exploding systems consumption rates, and how much have been used according to dates, types, and locations. If there were surplus of these materials after completion of relevant works, these extra quantities and blasting systems shall be returned to the authorities from whom they were received, and prepare an official minutes approved from the concerned authorities showing this, and delivering a copy to the Engineer.

3.6.4. Work Inspection before Covering

According to Article 30 of public works contract form, Contractor should not cover any work or start any subsequent works before inspection, testing, measuring, acceptance and handing over by the Engineer.

Contractor shall notify the Engineer in writing with completion of the works he intends to cover and their readiness for inspection and handing over. Within 24 hours from receiving the notice by the approved and agreed method, the Engineer shall inspect those works, conduct the required measurements and takes the written decision
on the possibility of covering the works or require from the Contractor to carry out the necessary repairs.

The Ministry has the right, when it deems necessary and when the Engineer could not investigate, inspect, and test the works during the period stipulated above and Contractor covers them, to instruct Contractor to uncover the unexposed works for inspection and testing. In case it was found that the works were technically unacceptable, Contractor shall incur all the costs arising from that, but if the works were found to be acceptable, the Ministry shall justify the time period required for inspection, re-covering, and compensate Contractor by the agreed method on the basis of the practiced methods in such cases.

3.7. Measurement and Payment

3.7.1. Work Measuring

According to Article 46 of the public works contract form, the quantities indicated in the BOQ are estimated quantities and actually executed quantities shall be measured for all items. Measuring shall include, for the purpose of payment the works which were executed, technically accepted, and handed over to the Engineer within the work limits shown on the drawings, specifications and/or specified only by the Engineer. No measurements shall be conducted for works outside the mentioned limits for the purpose of payment.

Executed and technically acceptable works shall be measured by using engineering practiced measuring methods and devices. Quantities are calculated according to the measuring units shown on the BOQ for each work item. All the measurements shall be conducted by the Contractor with the attendance of the Engineer promptly with work progress. Quantities are calculated by the Contractor and submitted to the Engineer for auditing together with the original copy of measuring results and cross sections, or dimensions of the elements according to which quantity calculations were made. All this shall be done before periodical payment date by a period sufficient enough for auditing and approval; providing that it shall not, by any means, be less than 5 days.

The Engineer shall keep a copy of all measurements and quantity calculations of executed works to be submitted to the Ministry at work end.

3.7.2. Payment Scope

Prices indicated in the contract are considered full compensation to the Contractor for all labor, and extraction, or production or supply of materials and mixes, transportation, work execution and finishing according to approved specifications and drawings. Also, submission of reports, mix design, work testing and measuring, protection and maintenance works, provision of required machines and equipments and all requirements for executing work items and servicing them during the guarantee period in accordance with approved drawings and specifications. Also, costs of work organization, general expenses, benefits, fees, and third party payments for any reason related to project works, in addition to costs of all works indicated in the contract documents, specifications, and drawings for which payment is not made separately but considered as included in some or all contract items.

3.7.3. Compensation for Modified Quantities

Modified quantities which are different from the estimated quantities indicated in the BOQ are paid according to the original rates stipulated in the contract for each work
item. No objection is accepted from the Contractor concerning benefit or loss in any work item. The modified quantity rates shall be within the modification rates, plus or minus, allowable in the contract.

3.7.4. Additional Work and Work According to Calculating Manpower

Additional works, which the Ministry assigns Contractor to carry out according to a variation order, are paid according to unit price or lump sum as the variation order may stipulate.

When payment is for all or some of the contract items and additional works is made based on calculating manpower i.e. man/month, Contractor shall daily submit a list of the names of all employees working in the project, their professions and the duties assigned to them. The Engineer shall verify employees attendance throughout the period for which he pays the Contractor. In this case payment shall be according to the rates table which includes monthly payment for each of them. Deduction shall be made from the wages of the absentees according to contract documents, providing that absence does not lead to any defect in the quality standard of the executed works.

Payment for machines and equipments work, when agreed in the contract to pay for their work on the basis of time period, shall be made according to actual work lists which show numbers and types of actually working machines in the project and time period of work for each one of them. Deduction shall be applied for absence from work or failure of each machine in the project, and for machines related to the work of those machines according to contract documents.

3.7.5. Unauthorized Work

Payment is made only for works executed in accordance with the dimensions, thickness, and at the sites shown on the drawings, and special specification or determined in writing by the Engineer. Contractor has no right to claim any costs for works which were executed outside the mentioned boundaries, except otherwise that occurred according to a written assignation approved from the Ministry before execution.

3.7.6. Lump Sum

When lump sum payment is specified in the contract, the indicated amount is considered as full compensation against work completion according to approved drawings and specifications.

3.7.7. Fixtures and Accessories

All fixtures and accessories are considered as charged to the prices of the work item in which they shall be used.

3.7.8. Payments

Payment for executed and technically accepted works from the Engineer, is made according to periodic payment certificates as specified in the contract, and a final payment arranged at completion of the works and after handing over.

3.7.8.1. Current Payment

Contractor shall prepare the current payment according to the approved form and the payment certificate shall include only works which were executed during the payment period and inspected, tested, accepted, and handed over by the Engineer. He
submits it to the Engineer for auditing and the latter compares the quantities indicated in the payment certificate with the quantities he accepted. If it was found that the payment certificate is compatible with the executed work, the Engineer then forwards it to higher authorities after approved by him, or he may return it to the Contractor to correct mistakes and shortages. Contractor shall enclose with the payment certificate all the enclosures which the Ministry may require.

3.7.8.2. Final Payment

When contract works are completed and preliminary handing over minutes are prepared, the Engineer and Contractor's representative shall calculate and count all executed and technically accepted quantities subject for payment. Contractor shall submit as-built drawings when contract indicate that, and provide adequate number of employees, systems and equipments required for measuring works and calculate quantities and due amounts after deducting all penalties and deductions incurred by the Contractor.

The payment is signed and approved by the Engineer and Contractor and quantities indicated in the final payment are considered final. In case Contractor does not accept the quantities indicated in this payment, he shall submit a written objection together. The Engineer studies Contractor's objections and verifies calculated quantities then with enclosing all proofs and documents which justify his objection within 10 days, give his view on Contractor's objection.

If Contractor made no objection during 10 days, the payment is considered as final and Contractor's objection shall not be accepted after that. Payment then is forwarded to the concerned authorities together with all the required documents stipulated in the contract and in the projects execution supervision procedures manual issued by the Ministry of municipal and rural affairs; to complete auditing and payment procedures.

3.8. Work Handing Over

Handing over of the works shall be according to contract documents in two stages: preliminary handing over and final handing over.

3.8.1. Preliminary Handing Over

Immediately after completion of works, Contractor shall notify the Ministry on work completion according to a letter approved from the Engineer. The Ministry shall form a handing in committee and the Engineer shall be one of its members. The committee studies all contract documents, periodic reports, results of tests and measurements, and shall review Contractor performed quality control records. Also, results of quality assurance results by the Ministry and informs the Contractor on the date of attending inspection of executed works on the field and carries this inspection with the attendance of Contractor. The committee has the right, when it deems necessary, to require carrying out some measuring and testing of some or all work items at its own discretion, or may become satisfied by visual inspection, quality control and quality assurance results.

The committee edits the preliminary handing over minutes according to one of the following cases:

1. Acceptance without any deductions when it surmises that works have been completed according to drawings and special specifications.
2. Preliminary handing over with some reservations which do not prevent getting use from the project and do not lead to technical fault. In such case it has the
right to apply deduction in the rate it considers as suitable for commented items; or existence of some shortages which were not executed, do not prevent use from the project, do not affect the project safety, it is possible to dispense with, and their value does not exceed 20% of contract total value. In such case the committee recommends handing in the project preliminarily providing that deduction against comments and shortages shall be made from the final payment.

3. Existence of some comments which, if Contractor does not repair, no use can be obtained from the project. In such case the committee requires Contractor to carry out the required repairs within a certain period and comes to verify that Contractor has conducted the required repairs.

Ministry may, when it considers there is a need for opening a part of the project to get use decide, according to notice from the Contractor, that part is ready for preliminary handing over. And it receives this part preliminarily and preliminary handing over procedures for this part are conducted according to the above mentioned. The guarantee period for that part starts from the date of its preliminary handing over.

Contractor remains responsible for protecting and maintaining project works during the guarantee period stipulated in the contract, and he shall carry out all the required maintenance works without having the right to claim any additional compensation for that.

3.8.2. Final Handing Over

When the guarantee period, specified in the contract, which starts from the date of preliminary handing over for project works or part of them expires, Contractor shall submit a request to the Ministry to carry out final handing over.

The Ministry forms a final handing over committee with the Engineer as member. The committee studies contract documents, testing and measuring results, quality control and quality assurance results, minutes and comments of preliminary handing over and specifies a date for attending work inspection physically carries out the inspection and prepares a minute, according to the following cases:

1. Receiving the works without comments when it is convinced that the works have been executed according to the drawings and specifications; and that no defects appeared on them arising from Contractor’s failure during the guarantee period.
2. Existence of some comments and in such case requires from the Contractor to carry out the required repairs within a certain period after which it returns back to complete handing over procedures.

The committee prepares the final handing over minutes and signs them from all parties the committee, Engineer, Contractor or representative and submits the minutes to the higher authorities to complete the required action.

Contractor remains responsible for all the defects, arising from improper execution or materials, which may appear during the period specified in the contract after final handing over is completed.
3.9. References


OKLAHOMA: “Oklahoma Department of Transportation Standard Specifications for Highway Construction-1999”.


MOT KSA; "General Specifications For Road And Bridge Construction"; November 1998.

SECTION 4. STRUCTURAL EXCAVATION AND BACKFILL

4.1. Description

4.1.1. General

This work consists of the removal of all material, of whatever nature, necessary for the construction of bridge foundations, retaining walls, tunnels, culverts, and other major structures in accordance with the contract documents or as directed by the Engineer.

If not otherwise provided in the contract documents, excavation work shall include the furnishing of all equipment necessary, material, and labor for the construction and subsequent removal of all cofferdams, shoring, and water control systems that may be necessary for the execution of the work.

It shall also include, if not otherwise specified in the contract documents, the placement of all necessary backfill, including any necessary stockpiling of excavated material which is to be used in backfill, and the disposing of excavated material, which is not required or suitable for backfill.

If the contract does not explicitly include a separate pay item, or items, for such work, excavation work shall include all necessary clearing and grubbing and the removal of existing structures within the area to be excavated.

Classification, if any, of excavation shall be indicated in the contract document and set forth in the Bill of Quantities.

Excavation and backfill shall be done in a reasonably close conformity with the lines, grades and typical cross sections shown on the contract drawings or established by the Engineer.

Temporary Shoring and Cribbing shall consist of the design and construction of shoring and cribbing required to support roadways or other public or private structures within 5 m of the excavation for the duration of the excavation, and backfilling operations, as detailed in Section 6, "Temporary Structures".

The Contractor shall visit the site and evaluate the geological make-up of the area for himself and base his bid prices solely on his own determination of geological conditions. Any information provided by the Ministry is for the Guidance only.

4.1.2. Classification

Excavation and backfill for structures are classified as follows:

4.1.2.1. Unclassified Excavation

It consists of the removal of all material, of whatever nature, for the construction of bridge foundations, retaining walls, tunnels, box culverts, channels, ditches at culvert inlets and outlets, and any other ditches as shown on the contract drawings or directed by the Engineer.
4.1.2.2. Unclassified Structural Excavation

It consists of the removal of all material, of whatever nature, below the level of Unclassified Excavation for the construction of box culverts, at the specified locations and elevations.

4.1.2.3. Common Substructural Excavation

It consists of the removal of all materials for the construction of bridge foundations, retaining walls, tunnels, culverts, channels, piers and abutments, except those classified as substructural rock excavation.

4.1.2.4. Substructural Rock Excavation

It consists of the removal of all rock, for the construction of substructures, piers and abutments. Rock ledges encountered above the foundation material and, boulders or pieces of concrete having a volume of $0.4 \text{ m}^3$ or more, will be classified under this item.

The amount of rock excavation shall be determined by the Engineer and agreed to by the Contractor while the excavation is open for inspection. Claims for additional quantities under this classification over the amount determined during the progress of the work will not be recognized.

4.1.2.5. Unclassified Backfill, Select Backfill, and Granular Backfill

It consists of supplying, placing, and compacting granular backfill material according to these specifications and the contract documents.

4.1.2.6. Controlled Low-Strength Material (CLSM) Backfill

It consists of supplying and placing of controlled low strength material in excavations, other confined or formed spaces.

4.2. Working Drawings

Whenever specified the Contractor shall provide working drawings, accompanied by calculations where appropriate, of excavation procedures, including bracing protection, if required, and backfilling operations. This plan shall show the details of shoring, bracing, slope treatment or other protective systems proposed for use and shall be accompanied by design calculations and any supporting data in sufficient detail to permit an engineering review of the proposed design.

The working drawings and plans for protection from caving shall be submitted sufficiently in advance of proposed use to allow for their review, revision, if needed and approval without delay to the work.

Working drawing must be approved by the engineer prior to performing work involved, and such approval shall not relieve the Contractor of any responsibility under the contract for the successful completion of the work.
4.3. Excavation

4.3.1. Inspection

4.3.1.1. General

The Contractor shall notify the Engineer a sufficient time in advance of the beginning of any excavation for structures that constitute a pay item in the Bill of Quantities so that the Engineer may observe the cross-sectional elevations and measurements taken of the existing ground in the area of the structure. Any materials removed or excavated or placed before taking these measurements will not be paid.

The Contractor shall minimize, to the extent possible, the length of time that excavated areas are open. He shall be solely responsible for damages due to weather, equipment, accidents, or other causes when excavation is left open.

In areas where the excavation is adjacent to public roads and walkways, the Contractor shall erect all barricades, barriers, enclosed walkways, and warning signs necessary to restrict the exposure of the public to the excavation. The adequacy of all such safety measures shall be submitted to the Engineer for approval.

The Contractor shall take all necessary precautions, including cofferdams and other shoring, to protect employees in the excavation and on the ground above. The Engineer will not enter excavated areas to approve the foundation and further work unless the areas are considered safe.

4.3.1.2. Approval

The Engineer shall perform the inspection of foundation pits and the measurement of material removed. In no case shall a foundation be closed to view, prior to allowing the Engineer to inspect and render his approval.

4.3.1.3. Change in Foundation Elevations

When in the Contractor's opinion, rock, or other firm foundation material of equal bearing value is encountered at an elevation above that shown in the contract documents for the footing, and at a location not prone to erosion or scour, the Contractor shall notify the Engineer in order to investigate and determine whether it is advisable to raise the level of the footing.

When the excavation for a footing has been completed to the approximate elevation shown on the plans without encountering satisfactory foundation material, the Contractor shall notify the Engineer in order to make an inspection and investigation. Such investigation may consist of drilling, probing, or jetting by the Contractor; a maximum of 4 holes per footing with each hole reaching a maximum depth of 6 m. No direct payment will be made for this operation. If additional holes are required, the Contractor shall be compensated as provided in this section. Consequently, the Engineer will then fix the proper elevation of the footing or decide upon its treatment.

4.3.1.4. Drilling or Probing

When apparently satisfactory foundation material has been reached, the Contractor shall drill or probe not more than 4 exploratory holes to a maximum depth of 3 m. The drilling will not be required if a note is shown on the plans to waive this requirement. No direct payment will be made for this operation. If additional holes are required, the Contractor shall be compensated as provided in this section.
4.3.2. Depth and Size of Excavation

The excavation for the bottom level of the footing shall be carried out to the depth as shown in the contract documents. The design and elevation of footings are based on soundings taken at certain points for design purposes only. These soundings may or may not be representative of the actual conditions encountered during construction. Bidders must assume the risk of having to excavate to a greater or lesser depth without altering the contract unit prices in the Bill of Quantities. The footing elevations shown on the plans shall be considered as approximate only. The Engineer may order, in writing, such changes in dimensions or elevations of footings as may be necessary or deemed fit to secure satisfactory foundations for the structure. The increase in footing size shall be paid at bid price.

The size of the excavation shall in all cases be ample to accommodate necessary forms down to rock, marl, Selma chalk or similar hard material suitable for embedment of footings; excavation in such materials shall be as near as possible to the neat lines of the footings and the footings poured without the use of forms. In hard materials that cannot be cut to neat lines with a pneumatic spade, line drilling along the neat lines not to exceed 230 mm center to center will be required. In dry soils, suitable for footing embedment, capable of providing stable, and neat footing lines, permission may be given to allow pouring of footings without the use of forms, otherwise, the excavation shall be sufficient for forming the foundations.

The horizontal limits of excavation shall not extend beyond what is required for sheeting, bracing, forms, and reinforcing cages.

4.3.3. Foundation Preparation and Control of Water

4.3.3.1. General

All substructures, where practical, shall be constructed in open excavation and, where necessary, the excavation shall be shored, braced, or protected by cofferdams constructed in accordance with the requirements of Article 6.3, "Cofferdams and Shoring" in Section 6, "Temporary Structures". When footings can be placed in dry site conditions without the use of cofferdams, backforms may be omitted with the approval of the Engineer, and the entire excavation shall be filled with concrete to the required elevation of the top of the footing. The additional concrete required shall be furnished and placed at the expense of the Contractor. Temporary water control systems shall conform to the requirements in Article 6.4, "Temporary Water Control Systems" in Section 6, "Temporary Structures".

4.3.3.2. Excavation within Channels

When excavation encroaches upon a live stream bed or channel, unless otherwise permitted, no excavation shall be made outside of caissons, cribs, cofferdams, steel piling, or sheeting, and the natural stream bed adjacent to the structure shall not be disturbed without permission from the Engineer. If any excavation or dredging is made at the site of the structure before caissons, cribs, or cofferdams are sunk or are in place, the Contractor shall, without extra charge, after the foundation base is in place, backfill all such excavations to the original ground surface or river bed with material satisfactory to the Engineer. Materials temporarily deposited within the flow area of streams from foundation or other excavation shall be removed and the stream flow area thereby freed from obstruction.
4.3.4. Foundations on Rock

When a foundation is to rest on rock, the rock shall be freed from all loose material, cleaned and cut to a fine surface, either level, stepped, or roughened, as may be directed by the Engineer. All seams shall be cleaned out and filled with concrete, mortar, or grouted before the footing is placed.

Where blasting is required to reach footing level, any loose, fractured rock caused by over break below bearing level shall be removed and replaced with concrete or grouted at the Contractor's expense.

Where rock, in either ledge, boulder formation, or other unyielding material is encountered in one portion of foundation for a concrete box culvert and a yielding material is encountered in an adjacent area of the foundation excavation for the same box culvert, such unyielding material shall be removed for a minimum depth of 600 mm and backfilled with material approved by the Engineer.

4.3.5. Foundations not on Rock

When a foundation is to rest on an excavated surface other than rock, special care shall be taken not to disturb the bottom of the excavation. The final removal of the foundation material to grade shall be made just before the placement of the footing.

Where the material below the bottom level of footings not supported by piles has been disturbed, it shall be removed and the entire space filled with concrete or other approved material at the Contractor's expense. Under footings supported on piles, the over-excavation or disturbed volumes shall be replaced and compacted as directed by the Engineer.

The Contractor may excavate in open pits when:
1. Worker safety is assured.
2. Footings can be placed in dry material, away from flowing water.
3. The integrity of the structure and its surroundings, including existing pavement, is not reduced.

Care shall be taken during excavation to prevent disturbing the foundation. If ground water is encountered during excavation and a concrete seal course is not to be used, dewatering shall be commenced and shall proceed in advance of or concurrently with further excavation. The foundation shall be free of water at the time footing concrete is placed, and water control shall continue as deemed necessary to prevent damage to the work.

All dewatering shall be performed at the Contractors sole expense and shall be considered as included in the contract unit price(s) for the facility being constructed. The sides of excavations may be sloped as required by soil conditions to stabilize the sides for safe working conditions. The quantities of excavation for said sloping will not be measured for payment and backfilling of the same shall be done with suitable materials, approved by the Engineer, at the Contractors expense.

If suitable foundation material has been disturbed by the Contractors operations, has been damaged by the water, or has been removed for the Contractors convenience in dewatering the foundation, the foundation shall be restored at the Contractor's expense, to a condition at least equal to the undisturbed foundation as determined by the Engineer.
4.3.6. Pile Excavation

Where foundation piles are used, the excavation of each pit shall be completed before the piles are driven. All the foundation piling shall be driven before concrete is placed in any column of that pier or abutment.

When footings are to be supported on piles, excavations shall be completed to the bottom of footings before any piles are drilled or driven therein. When swell or subsidence results from driving piles, the Contractor shall at his expense, excavate, or backfill with suitable material, the footing area to the grade of the bottom of footing as shown on the plans. If material under footings is such that it would mix into the concrete during placement or would not support the weight of the fluid concrete, the Contractor shall, at his expense, replace the material with suitable material, install soffit forms or otherwise provide a suitable platform on which to cast the footing.

4.3.7. Tunnel Excavation

The Contractor shall use excavation methods that minimize excavation outside the limits of the excavation lines as defined on the Plans. Excavation outside the excavation lines (overbreak) is the responsibility of the Contractor. Enlargements of any underground opening for the convenience of the Contractor will not be allowed without prior written approval of the Engineer.

As the excavation proceeds, the Contractor shall check the crown and walls over the unsupported lengths of tunnel after each advance, and scale all loose and shattered material. He shall also carry out similar checks on previously excavated sections that have not been covered with shotcrete at the end of each shift until stability can reasonably be assumed in the opinion of the Engineer. The Contractor shall provide the Engineer with access to crown and sidewalls in these areas at least once per shift.

The Contractor shall maintain neat working conditions at all times inside the tunnels and remove all muck, unusable materials and any other material not required for the work. Explosive excavation (blasting) shall be carried out by a qualified and licensed contractor in a manner to minimize air overpressure and ground vibrations at nearby structures. The Contractor shall use blasting procedures and curtains to provide effective suppression of vibrations and employ other abatement measures necessary for the protection of both employees and the public. Compliance with this section will not relieve the Contractor from responsibility for compliance with local ordinances, regulations and other Sections.

Overbreak areas will need backfilling with shotcrete and/or cast-in-place concrete as indicated herein and/or indicated in the plans. This extra support is considered corrective and backfilling overbreak areas with shotcrete and/or cast-in-place concrete shall be at the Contractor's expense.

4.3.8. Approval

After each excavation is completed, the Contractor shall notify the Engineer, and no concrete or other footing material shall be placed until the Engineer has approved the depth of the excavation and the characteristics of the foundation material.

4.3.9. Permits and Licenses

The Contractor shall be responsible for obtaining all applicable blasting permits and licenses required by the Ministry of Interior/Public Security officials, or any other authority that has an oversight over the construction site.
The Contractor is responsible for control of water in the tunnel during construction and shall take all means necessary for such control. Control of water shall include, but not limited to, furnishing, installing, operating, and maintaining pumps and other equipment; constructing temporary drains and keeping ditches free to carry all water quickly to sediment basins or other disposal areas; and disposal of all water draining or pumped from the tunnel.

Tunnel drainage water shall be treated in conformance with the Kingdom and local jurisdiction's water quality criteria before discharging water into the natural drainage channels or streams. Petroleum residues shall be removed by oil soaks to the satisfaction of the Engineer.

All products and materials used for rock excavation, either explosive or nonexplosive, are subject to approval by the Engineer. Only explosives, explosive components, and detonators commercially manufactured within the previous two years or the shelf life of the product, whichever is less, shall be used.

At all times, the Contractor shall keep sufficient materials (rock bolts, shotcrete, etc.) near the tunnel excavation heading to provide a secure tunnel face.

Work shall be performed in a manner to minimize hazards to construction personnel. Safety in excavating shall be the responsibility of the Contractor.

4.4. Backfilling

4.4.1. General

Backfill material shall conform to the provisions of Article 4.4.2 "Materials". If sufficient material conforming to Article 4.4.2 of this Section is not available from excavation within the project limits, the Contractor shall import such material as directed by the Engineer.

Unless otherwise specified in the contract documents, all spaces excavated and not occupied by abutments, piers, or other permanent work shall be refilled with earth up to the surface of the surrounding ground, with a sufficient allowance for settlement. Except as otherwise provided, all backfill shall be thoroughly compacted to the density of the surrounding ground and its top surface shall be neatly graded. Fill placed around piers shall be deposited on both sides to approximately the same elevation at the same time. Rocks larger than 75 mm maximum dimension shall not be placed against the concrete surfaces.

Embankment construction shall conform to the requirements of Article 5.4 in “General Specification of Urban Road Construction”. The fill at retaining walls, abutment, wingwalls, and all bridge bents in embankment shall be deposited in well-compacted, horizontal layers not to exceed 150 mm in thickness and shall be brought up uniformly on all sides of the structure or facility. Backfill within or beneath embankments, within the roadway in excavated areas, or in front of abutments and retaining walls or wing walls shall be compacted to the same density as required for embankments.

No backfill shall be placed against any concrete structure until permission has been given by the Engineer. The placing of such backfill shall also conform to the requirement in Article 10.17.2, "Earth Loads" in Section 10, "Concrete Structures". The backfill in front of abutments and wing walls shall be placed first to prevent the
possibility of forward movement. Jetting of the fill behind abutments and wing walls will not be permitted.

Adequate provision shall be made for the thorough drainage of all backfill. Trench drains, consisting of at least 0.06 cubic meters of permeable material wrapped in filter fabric to prevent clogging and transmission of fines from the backfill, shall be placed at weep holes.

Backfilling of metal and concrete culverts shall be done in accordance with the requirements of Section 25 "Steel Culverts" and Section 26 "Concrete Culverts".

4.4.2. Materials

Materials used in structural backfill shall be materials of A-2-4 type as in Standard Specifications for Transport Materials and Method of sampling 16th edition 1993 Part-1 Specifications or better and its plasticity index 5 or less when tested according to AASHTO T-90 test.

Backfill materials shall be, free from organic materials and the percent by weight of sulphates and carbonates shall not be more than five-tenth percent (0.5%) according to AASHTO T-(290-291). The backfill material shall not contain rock fragments having maximum dimension of more than 75 mm.

Unless otherwise specified the gradation granular materials used in backfill for structures shall meet the gradation limits in Table 4.1.

Permeable material for underdrain shall conform to AASHTO Guide Specifications for Highway Construction, Subsection 704.01.

<table>
<thead>
<tr>
<th>Sieve size, mm (sieve No)</th>
<th>Percent Passing by weight, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>75mm (3 inches)</td>
<td>100</td>
</tr>
<tr>
<td>19mm (3/4 inch)</td>
<td>60-100</td>
</tr>
<tr>
<td>2.36mm (No. 8)</td>
<td>35-80</td>
</tr>
<tr>
<td>0.075mm (No. 200)</td>
<td>0-12</td>
</tr>
</tbody>
</table>

4.4.2.1. Controlled Low-Strength Material (CLSM)

1. General

CLSM shall be made from materials (Portland Cement, Fly Ash (optional), Fine Aggregate, Water, Air Entraining Agent (optional) conforming to Section 10 "Concrete Structures".

2. Mix Design

The sample mix proportions shall be used as given in Table 4.2 as a guide to proportioning CLSM. The mix design shall be adjusted to account for differences in specific gravities and bleeding rate, and to comply with the testing requirements. The absolute volume method shall be used to design the mix.
Table 4.2: Sample CLSM Mix Design

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Unit (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>12-30</td>
</tr>
<tr>
<td>Fly Ash (optional)</td>
<td>90-150</td>
</tr>
<tr>
<td>Sand (saturated-surface-dry condition)</td>
<td>1700-1800</td>
</tr>
<tr>
<td>Water</td>
<td>120-300</td>
</tr>
</tbody>
</table>

3. Sampling and Testing

Ample CLSM shall be provided for field testing. The testing methods are as follows:

a. Flow Test

Flow tests shall be conducted in accordance with ASTM D 6103, “Standard Test Method for Flow Consistency of Controlled Low Strength Material” to be acceptable, the diameter of the CLSM spread must equal or exceed 200 mm.

b. Unit weight

Unit weight tests shall be conducted in accordance with ASTM D 6023, “Standard Test Method for Unit Weight, Yield, Cement Content, and Air Content (Gravimetric) of Controlled Low Strength Material”. A deviation of five percent (5%) in measured unit weight from the approved mix design value will be cause for rejection of a CLSM batch.

c. Strength Test

Compressive strength tests shall be conducted in accordance with ASTM D 4832, “Standard Test Method for Preparation and Testing of Controlled Low Strength Material.” Strength shall be measured at 28 days. The Contractor may test CLSM strength earlier than 28 days to confirm the material placed has reached the minimum required strength. Report all cylinder breaks. To be acceptable, the compressive strength must be more than 0.7 MPa and less than 8 MPa. If 28 day strengths exceed 8 MPa, adjust the mix design to reduce strength.

4.4.3. Foundation Preparation

If the surface upon which the footing is to be placed becomes soft or muddy and will not dry out after the excavation has been dewatered, the Engineer may direct that a foundation course of approved free draining material, as specified in Article 4.4.2, be used under the footing.

If this soft and muddy condition occurred through no fault or negligence of the Contractor, the Engineer, at his discretion, may order payment to be paid as specified in Article 4.6.2, "Payment", in this Section.

When the above condition occurs as a result, in the opinion of the Engineer, of negligence on the part of the Contractor, no payment will be made for the required foundation backfill. Compaction shall be as directed by the Engineer.

4.4.4. Preservation of Stream Banks and Channel

The natural ground adjacent to the structure shall not be disturbed without permission of the Engineer. Unless otherwise specified, no excavation shall be made
outside of caissons, cribs, cofferdams, steel piling or sheeting. The natural stream bed adjacent to the structure shall not be disturbed without permission from the Engineer. If any excavation or dredging is permitted at the site of the structure before caissons, cribs or cofferdams, or piling are placed, the Contractor shall, without extra compensation and after the foundation is in place, backfill all such excavations to the original or established ground surface or stream bed with satisfactory material. No material or debris shall be deposited in any designated navigation channel during construction except with the approval of the Engineer. Such material or debris shall be removed to the normal navigation channel depth prior to completion and acceptance of the contract. Any material or debris resulting from the Contractor's operations deposited outside any designated navigation channel or other streams during construction, with the exception of fill originally as may be ordered as a permanent part of the work, shall be removed and the channel freed from all obstructions before completion of the work.

4.4.5. Disposal of Surplus and Unsuitable Material

Surplus excavated material, after piers and abutments are backfilled, shall be used to obliterate construction scars at or near the bridge site, to smooth out depressions in and near the stream banks or as otherwise directed by the Engineer.

4.5. Works Acceptance:

Contractor shall apply quality control for structural excavation and backfill work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in the special specifications and client’s specifications or general specifications and other contract documents.

The Ministry shall apply quality assurance and verify the Contractor quality control procedures either through direct supervision or by carrying out neutrally quality assurance procedures using test on representative samples and in adequate numbers to judge about the quality level and accept or reject the executed works according to the principles detailed mentioned bellow in next paragraphs.

4.5.1. Quality Control:

4.5.1.1. Cut

The contractor must do the all require procedures of excavation works quality control to insure that the construction methods and executing works are satisfying the quality requirements which mention in Article 4.3.

4.5.1.2. Backfill

The contractor must do the all require procedures of backfill works quality control to insure that the used materials and construction methods and executing works are satisfying the quality requirements which mention in Article 4.4. Also all used material should satisfy the acceptance test limits that mentioned in Table 4.5.
4.5.2. Quality Assurance:

4.5.2.1. Cut

Ministry, at any time, has the right to assure the quality of excavation works through carrying out or ordering others to carry out under its supervision the tests and measurements for constructed works according to the Article 4.3.

4.5.2.2. Backfill

The ministry has the right at any time to the quality assure materials and executed works by performing or by assigning under its supervision testing the materials of backfill works and inspection of the executed work for each or some quality control items specified in Article 4.4 and the laboratory tests listed in Table 4.5.

4.6. Measurement and Payment

4.6.1. Measurement

4.6.1.1. General

Excavation for structures will be measured by volume in units of cubic meter. The volume will be computed based upon the material actually removed from its original position within the limits specified below, or as shown on the contract drawings. Additional volume caused by slips, slides, cave-ins, silting or filling due to the action of the elements or carelessness will not be measured for payment. Water will not be classified as excavated material. The disposal of excess material will not be measured and paid for separately, but will be considered incidental to the various classes of excavation and removal. Additional concrete required to fill any excavation outside the neat lines shown on the contract drawings will not be measured for payment.

4.6.1.2. Excavation for Substructures Supported by Piles

Excavation for substructures, piers and abutments, supported on piling will be measured as Common Substructural Excavation. The excavation volume for each substructure will be bounded by the existing ground surface, the bottom of the footing, and vertical planes 1 m outside the neat lines of the footing for the entire depth of the excavation. The existing ground surface will be the bottom of channel excavation when channel excavation is specified in the contract documents or directed by the Engineer.

4.6.1.3. Excavation for Substructures Supported on Natural Foundation Materials

Excavation for substructures, piers and abutments that are supported on natural foundation materials will be measured as either Common Substructural Excavation, or Substructural Rock Excavation. The excavation volumes will be computed as described in Article 4.6.1.2, "Excavation for Substructures Supported by Piles", except the quantity below the top of the approved foundation material, will be computed within the neat lines of footings as shown on the contract drawings or as directed by the Engineer. Measurement of abutment excavation volumes will be based on contract drawings quantities.
4.6.1.4. Excavation for Box and Pipe Culverts

1. Box Culverts
   Excavation from upper limit plane to the formation level of foundation shall be limited by vertical planes three hundred 300 mm outside the culvert dimensions in plan. Excavations for toe walls shall be limited to the actual depth of toe walls plus the blinding concrete and vertical planes walls 300 mm outside the outer faces of the toe walls.

2. Pipe Culverts
   Excavation from the bottom of the pipe bedding plane to the bottom of the unsuitable foundation material excavation shall be limited by the pipe trench width limits 300 mm as larger than the pipe outside diameter.

4.6.1.5. Excavation for Tunnels
   The tunnel Excavation shall be measured in cubic meters, the volumetric measurements shall be taken as follows:
   - The volume will be computed to the theoretical excavation lines including shotcrete leveling, concrete lining, road pavement and subgrade layers and drainage channels.
   - Utility duct excavation below the bottom of the subgrade zone will not be included in the tunnel excavation quantity. It will be considered part of the utility Bill of Quantities item.
   - Excavation beyond the theoretical excavation lines (over break) is the responsibility of the Contractor.

4.6.1.6. Excavation for Bracing
   Excavation necessary to place sway bracing, sash bracing and bulkheads on timber substructures will not be paid for as a separate item, but will be included in the price bid for such construction items.

4.6.1.7. Backfilling
   Backfill, for each type of specified backfill material, will be measured by volume within the neat lines shown on the contract drawings or as directed by the Engineer.

4.6.1.8. Special Conditions
   When the Contractor encounters special or unusual conditions he shall notify the Engineer who may direct special structural excavation limits where he deems them necessary. Any additional excavation because of special conditions, performed by the Contractor without prior approval of the Engineer, shall be at the Contractor's expense and no subsequent measurement or payment will be made.

4.6.2. Payment
   Unless otherwise provided, structure excavation, measured as provided in the above Article 4.6.1, "Measurement", will be paid for by the cubic meter for the kind and class specified.
   Payment for structural excavation shall include full compensation for all labor, material, equipment, and other item that may be necessary or convenient to the successful completion of the excavation to the elevation of the bottom of footings or base of structure.
Full compensation for controlling and removing water from excavations and for furnishing and installing or constructing all cofferdams, shoring, and all other facilities necessary to the operations, except concrete seal course that are shown on the plans, and their subsequent removal, shall be considered as included in the contract price for structure excavation, unless the contract provides for their separate payment.

The contract price for structural excavation shall include full payment for all handling, processing and storage or replacement of excavated materials, which are to be used as backfill, including any necessary drying, and the disposal of all surplus or unsuitable excavated materials, unless otherwise provided for in the contract. Any clearing, grubbing, or structure removal which is required, but not paid for under other item of the contact, will be considered to be included in the price paid for structure excavation.

Unless the contract provides for its separate payment, the contract price for structure excavation shall include full compensation for the placing and compacting of structure backfill. The furnishing of backfill material from sources other than excavation will be paid for at the contract unit price for the material being used or as extra work if no unit price has been established.

Payment will be made under one or more of the items in Table 4.3.

Table 4.3: Structural Excavation And Backfill Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1.2.1</td>
<td>Unclassified Excavation</td>
<td>Cubic meter</td>
</tr>
<tr>
<td>4.1.2.2</td>
<td>Unclassified Structural Excavation</td>
<td>Cubic Meter</td>
</tr>
<tr>
<td>4.1.2.3</td>
<td>Common Substructural Excavation</td>
<td>Cubic Meter</td>
</tr>
<tr>
<td>4.1.2.4</td>
<td>Substructural Rock Excavation</td>
<td>Cubic Meter</td>
</tr>
<tr>
<td>4.1.2.5</td>
<td>Unclassified Backfill, Select Backfill, and Granular Backfill</td>
<td>Cubic Meter</td>
</tr>
<tr>
<td>4.1.2.6</td>
<td>Controlled Low-Strength Material (CLSM) Backfill</td>
<td>Cubic Meter</td>
</tr>
</tbody>
</table>
### Table 4.4: Quality Control Requirements For Excavation And Backfill

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Excavation</td>
<td>Observing the cross-sectional elevations and measurements</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>Once</td>
<td>Article 4.3.1.1</td>
</tr>
<tr>
<td></td>
<td>Erect all barricades, barriers, enclosed walkways, etc.</td>
<td>Surveying</td>
<td>In situ</td>
<td>Until the area are considered safe</td>
<td>Article 4.3.1.1</td>
</tr>
<tr>
<td>Excavation</td>
<td>Drilling, probing, or jetting as necessary</td>
<td>Each hole reaching a maximum depth of 6 m</td>
<td>In situ</td>
<td>Maximum of four holes per footing</td>
<td>Article 4.3.1.3</td>
</tr>
<tr>
<td>After Excavation</td>
<td>Depth of excavation measurement</td>
<td>In situ</td>
<td>Once</td>
<td></td>
<td>Article 4.3.2</td>
</tr>
</tbody>
</table>

### Table 4.5: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMITES</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI≤5</td>
<td>AASHTO T-90</td>
<td></td>
<td>The plastic limit of a soil is the lowest water content at which the soil remains plastic</td>
</tr>
<tr>
<td>Carbonates Percent≤0.5% and rock fragments dimension≤75mm</td>
<td>AASHTO T- (290)</td>
<td></td>
<td>Standard Method of Test for Determining Water-Soluble Sulfate Ion Content in Soil</td>
</tr>
<tr>
<td>Water-Soluble Chloride Percent≤0.5%</td>
<td>AASHTO T-291</td>
<td>ASTM D 6103</td>
<td>Standard Method of Test for Determining Water-Soluble Chloride Ion Content in Soil</td>
</tr>
<tr>
<td>diameter of the CLSM spread≥200 mm</td>
<td></td>
<td>ASTM D 6023</td>
<td>Standard Test Method for Flow Consistency of Controlled Low Strength Material (CLSM)</td>
</tr>
<tr>
<td>Deviation in measured unit weight&lt;5%</td>
<td>ASTM D 6023</td>
<td>ASTM D 6023 - 07</td>
<td>Standard Test Method for Density (Unit Weight), Yield, Cement Content, and Air Content (Gravimetric) of Controlled Low-Strength Material (CLSM)</td>
</tr>
<tr>
<td>0.7-8 MPa after 28 days</td>
<td>ASTM D 4832</td>
<td>ASTM D 6023</td>
<td>Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders</td>
</tr>
</tbody>
</table>
4.7. References


AASHTO LRFD Bridges Construction Specifications -2004. Sec. 1


MOT KSA;"General Specifications For Road And Bridge Construction"; November 1998.


SECTION 5. REMOVAL OF EXISTING Structures

5.1. Description
This work shall consist of the removal, wholly or in part, and satisfactory disposal of all buildings, bridges, culverts, fences, structures, old pavements, abandoned pipe lines, and any other obstructions, which are designated for removal. It shall also include the salvaging of designated materials and backfilling the resulting trenches, holes, and pits.

This work, when specified, shall also consist of removing designated traffic signal and highway lighting items, such as pole assemblies, luminaries, pull boxes, power supplies, signal heads, controllers, and other related electrical equipment; these shall be delivered to a location specified on the Plans and in a manner approved by the Engineer. This work shall also consist of removing abandoned items and restoring the site to match the surrounding conditions.

When the proposal does not include pay items for removal of structures and obstructions as set out in this Section, the cost of such work shall be included in other items.

5.2. Working Drawings
Working drawing showing methods and sequence of removal shall be prepared for the following cases:

- When the structure or portions of the structure are specified to be removed and salvaged.
- When removal operations will be performed over or adjacent to public traffic or railroad property, or
- When called for by the plans or special provision. At least 10 days prior to the proposed start of removal operations, the working drawings shall be submitted to the Engineer for approval.

Removal work shall not begin until the drawings have been approved. Such approval shall not relieve the Contractor of any responsibility under the contract for the successful completion of the work.

When salvage is required, the drawing shall clearly indicate the markings proposed to designate individual segments of the structure.

5.3. Construction
5.3.1. General
Except for utilities and other items that the Engineer may direct the Contractor to leave intact, the Contractor shall raze, remove and dispose of each structure or portion of structure, designated for removal. All concrete and other foundations shall be removed to a depth of at least 0.6 m below ground elevation or 0.9 m below subgrade elevation, whichever is lower. Unless otherwise specified in the contract documents, the Contractor has the option to either pull piles or cut them off at a point not less than 0.6 m below ground line. Cavities left from structure removal shall be backfilled to the
level of the surrounding ground and, if within the area of roadway construction, shall be compacted to meet the requirements of the contract for embankment.

Explosives shall not be used except at locations and under conditions cited by the project specification. All blasting shall be completed before the placement of new work.

5.3.2. Partial Removal of Structures

When structures are to be widened or modified and only portions of the existing structure is designated for removal, these portions shall be removed in such a manner as to leave the remaining structure undamaged and in proper condition for the intended use. Methods involving the use of blasting or wrecking balls shall not be used within any span or pier unless the entire span or pier is to be removed. Any damage to the portions remaining in service shall be repaired by the Contractor's expense.

Before beginning concrete removal operation involving the removal of a portion of a monolithic concrete element, a saw cut approximately 26 mm deep shall be made to a true line along the limits of removal on all faces of the element which will be visible in the completed work.

Old concrete shall be carefully removed to the lines designated by drilling, chipping, or other methods approved by the Engineer. The surfaces presented as a result of this removal shall be reasonably true and even, with sharp straight corners that will permit a neat and workmanlike joint with the new construction or be satisfactory for the purpose intended. Where existing reinforcing bars are to be extended from the existing structure into new construction, the concrete shall be removed so as to leave the projecting bars clean and undamaged. Where projecting bars are not to be extended into the new construction, they shall be cut off, flush with the surface of the old concrete.

During full depth removal of deck concrete over steel beams or girders, which are to remain in place, the Contractor shall exercise care so as not to notch, gouge, or distort the top flanges with jackhammers or other tools. Any damage shall be repaired at the Contractor's expense. Repairs will be done as directed by the Engineer and may include grinding, welding, heat straightening, or member replacement, depending on the location and severity of the damage.

5.3.3. Demolition

If the Contract requires demolition, the existing Structures shall be removed and the existing surface shall be restored to.

Before beginning demolition, the Contractor shall coordinate disconnection of utility services with the appropriate utility owner.

Broken or damaged utilities shall be repaired immediately, at no additional payment to the Contractor.

5.3.4. Removal of Bridges, Culverts and other Existing Structures

Bridges and culverts in use by traffic shall not be removed until alternative arrangements have been made to accommodate traffic.

When structures are to remain the property of the Owner, the method of dismantling steel superstructure and wood bridges shall avoid inflicting any damage to the materials. Before dismantling, steel members shall be match marked for re-erection purposes by painting them, and by using steel stencils in a manner approved by the
Engineer. Steel members at the original field splices shall be dismantled and supported on falsework during the operation of dismantling, or in a manner and method approved by the Engineer.

*Note:* Any damaged steel shall be replaced or satisfactorily repaired by the Contractor without compensation.

Piers, abutments, and piling shall be cut at the ground line, or in case of channel change, at the elevation of the channel excavation as shown on the Plans.

Salvaged lumber, structural steel, etc. shall be stacked on the right-of-way outside of the ditch line in a neat and workmanlike manner.

Old concrete and other similar materials shall be broken up and placed in the fill as specified for placing solid rock in fills, or otherwise disposed off as directed by the Engineer.

Where such portions of existing structures lie wholly or in part within the limits for a new structure, they shall be removed as necessary to accommodate the construction of the proposed structure.

*Note:* In no case shall material be left in the channel.

When blasting or other operations necessary for the removal of an existing structure or obstruction, which may damage new construction, these operations shall be completed before the placing of the new work.

When structures or material in structures are to become the property of the Contractor, the Contractor shall remove and dispose of the material in accordance with these specifications. Piers, abutments, piling, and substructures shall be removed as specified in this Article.

### 5.3.5. Removal of Sewer Pipe

Unless otherwise provided, the removal of all salvageable culverts and sewer pipes shall be achieved taking every precaution to avoid breaking and damaging the pipes. If pipes are to be re-laid, they shall be removed and stored so that there will be no loss or damage before relaying.

The Contractor will be required to replace sections lost from storage or damaged by negligence or by use of improper methods.

### 5.3.6. Removal of Pavement, Sidewalks, Curbs, Etc

All concrete pavement, base course, sidewalks, curbs, gutters, etc. designated for removal shall be broken into pieces weighing no more than 0.7 kN; they shall be stockpiled at designated locations shown on the Plans, or in a manner approved by the Engineer.

There will be no separate payment for excavating, removal of structures and obstructions, or for backfilling and compacting the remaining cavity.

When the removal of asphalt concrete or Portland cement concrete pavement is specified, the joint shall be sawed in a manner approved by the Engineer. Sawing shall be reasonably true to line, and the depth of sawing shall be such that when removing the material, there will be no undue under breakage or shattering of the adjacent area.

### 5.3.7. Salvage

Materials that are designated to be salvaged under the contract, for reuse the project or for future use by the owner, shall remain the property of the owner and shall be
carefully removed in transportable sections and stockpiled near the site at a location
designated by the Engineer. The Contractor shall restore or replace damaged or
destroyed material without additional compensation.

Rivets and bolts that must be removed from steel structures to be salvaged shall be
removed by cutting the heads with a chisel, then punched or drilled from the hole, or by
a method that will not damage the members for reuse and shall meet the approval of the
Engineer. All members or sections of steel structures shall be match-marked with paint
accordance with the diagram or plan approved by the Engineer prior to dismantling.

All bolts and nails shall be removed from lumber deemed salvageable by the
Engineer as part of the salvage of timber structures.

5.3.8. Abandoned Structures
All abandoned existing structures shall be broken off and removed to a depth of not
less than 150 mm below the foundation grade of new structure. When sewer lines,
water lines, etc. are to be abandoned, they must be tightly plugged at each end with
concrete in the manner approved by the Engineer.

Manholes and similar structures to be abandoned shall be removed to the depth
specified, and shall be filled and compacted with suitable material. If the structure
abandoned and so backfilled is to be under paving or another structure, the backfill
material shall be tamped and compacted in uniform layers not exceeding 150 mm in
thickness.

If the structure is not under paving or other structures, settlements may be obtained
by thoroughly flushing with water during backfill operations.

5.3.9. Disposal of Abandoned Materials
Any abandoned concrete footing, concrete apron, conduit, and other miscellaneous
material shall belong to the Contractor and shall be removed and disposed of in a
manner approved by the Engineer. Materials such as drop inlet grates and frames,
manhole covers and frames, concrete or clay pipe, water pipe, goosenecks, valves,
stops, valve boxes, or any material of value shall become the property of the
Contractor, unless the Plans or Special Provisions provide otherwise for their disposal.

Except as provided herein, the Contractor shall store or dispose of such material
outside of the right of way. If the material is disposed of on private property, the
Contractor shall secure written permission from the property owner and shall furnish a
copy of each agreement to the Engineer. Waste materials may be disposed of in owned
sites described in the special provisions.

Unless otherwise provided in the special provisions, removed concrete may be
buried in adjacent embankments, provided it is broken into pieces which can be readily
handled and incorporated into embankments and is placed at a depth of not less than
1 m below finished grade and slope lines. The removed concrete shall not be buried in
areas where piling is to be placed or within 3 m of trees, pipelines, poles, buildings, or
other permanent objects or structures, unless permitted by the Engineer.

5.4. Works Acceptance
Contractor shall apply quality control for removal of existing structure work
through carrying out all the required procedures to insure that, completion methods and
completed works fulfill quality requirements stipulated in the article [3.6], "control and
acceptance of materials and work".
5.4.1. Quality Control

The contractor must do all require procedures of removal the existing structure works quality control to insure that the construction methods and executing works are satisfying the quality requirements which mention in article \ref{5.3} from this general specifications.

5.4.2. Quality Assurance

Ministry has the right to assure the quality of removal the existing structure works through carrying out or ordering others to carry out under its supervision the tests and measurements for constructed works according to the article \ref{5.3} from this specification.

5.5. Measurement and Payment

The work as prescribed for by this item shall be measured as each individual structure, or portion of a structure, to be removed. Payment will be made on the basis of the lump sum bid price for the removal of each structure, or portion of structure, as specified.

Prices and payment shall include full compensation for all work, labor, tools, equipment, excavation, backfilling, materials, and incidentals necessary to complete the work, including salvaging materials not to be reused in the project when such salvaging is specified and not otherwise paid for.

Full compensation for removing and salvaging materials that are to be reused in the project shall be considered as included in the contract prices paid for reconstructing, relocating or resetting the items that may be designated in the contract, and no additional compensation will be allowed therefore.

Payment will be made under one or more of the items in Table \ref{5.1}. And Table \ref{5.2} show the Quality Control Requirements For removal of Existing Structures.

Table 5.1: Removal of Existing Structures Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
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</thead>
<tbody>
<tr>
<td>5.3.2</td>
<td>Partial Removal of Structures</td>
<td>Lump Sum</td>
</tr>
<tr>
<td>5.3.3</td>
<td>Demolition</td>
<td>Contingent Sum</td>
</tr>
<tr>
<td>5.3.4</td>
<td>Bridges, Culverts and other Existing Structures</td>
<td>Lump Sum</td>
</tr>
<tr>
<td>5.3.5</td>
<td>Sewer Pipe</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>5.3.6</td>
<td>Pavement, Sidewalks, Curbs, Etc</td>
<td>Square Meter</td>
</tr>
<tr>
<td>5.3.7</td>
<td>Salvage</td>
<td>Included</td>
</tr>
<tr>
<td>5.3.8</td>
<td>Abandoned Structures</td>
<td>Lump Sum</td>
</tr>
<tr>
<td>5.3.9</td>
<td>Disposal of Abandoned Materials</td>
<td>Lump Sum</td>
</tr>
</tbody>
</table>
Table 5.2: Quality Control Requirements For removal of Existing Structures

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal of concrete and other foundations</td>
<td>Removal depth shall be 0.6 m below ground elevation or 0.9 m below sub-grade elevation</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>Once</td>
<td>Article 5.3.1</td>
</tr>
<tr>
<td></td>
<td>Backfilling cavities left from structure removal</td>
<td>Surveying</td>
<td>In situ</td>
<td>Once</td>
<td>Article 5.3.1</td>
</tr>
<tr>
<td>Explosion</td>
<td>All blasting shall be completed before the placement of new work.</td>
<td>Surveying</td>
<td>In situ</td>
<td>Until the area are considered safe</td>
<td>Article 5.3.1</td>
</tr>
</tbody>
</table>

5.6. References

AASHTO LRFD Bridges Construction Specifications -2004.


MOT KSA;"General Specifications For Road And Bridge Construction"; November 1998.

SECTION 6. TEMPORARY STRUCTURES

6.1. General

6.1.1. Description

This work consists of the construction and removal of temporary facilities, which are generally designed and employed by the contractor to execute the work and whose failure or malfunction could affect negatively the contract work or put in danger the safety of adjacent facilities, property, or the public. Such facilities include: falsework, forms and form travelers, cofferdams, shoring, water control system, and temporary bridges.

Forms are the enclosures or panels which contain the fluid concrete and resist the forces due to its weight, placement, and consolidation. Forms may in turn be supported on falsework.

Falsework is any temporary structure that supports structural elements of concrete slabs, girders, steel, masonry or/and other structural elements during their construction until the structure is completed to the point it can support itself.

6.1.2. Working Drawings

Drawings of the required falsework design shall be prepared and submitted according to Subsection "Plans and Working Drawings" in MA-100-P-V1/1 of these specifications. Drawings shall include the following, as applicable, and delineated in the following subsections.

6.1.2.1. General

The Contractor shall design and show the details for constructing falsework that provides the necessary rigidity, supports the imposed loads, and produces the required lines and grades in the finished structure. A professional engineer in structural design shall be used to design, sign, and seal the drawings. The design calculations shall show the stresses and deflections in load supporting members.

6.1.2.2. Submission Sets

The Contractor shall submit three sets of falsework drawings and one set of design calculations for approval.

6.1.2.3. Design Details

The Contractor shall include the information and details necessary to enable falsework construction without reference to any supplemental drawing, calculation sheet, design standard, or other source document. He shall show all design-controlling dimensions, including beam length, beam spacing, post location and spacing, vertical distance between connections in diagonal bracing, height of falsework bents, and similar dimensions controlling falsework design and erection.
6.1.2.4. Foundation Loads
The Contractor shall show the maximum applied structural load on the foundation material including a drainage plan or description of how foundations will be protected from saturation, erosion, and/or scour.

6.1.2.5. Materials Specifications
The Contractor shall precisely describe all proposed falsework material. He shall describe also the material that is not designated by standard nomenclature (such as AASHTO or ASTM specifications) based on manufacturer’s tests and recommended working loads. The Contractor shall evaluate falsework material and ascertain whether the physical properties and conditions of the material are such that it can support the loads assumed in the design.

6.1.2.6. Concrete Placement
The Contractor shall provide an outline of the proposed concrete placement operation listing the equipment, labor, and procedures to be used for the duration of each operation. Include proposed placement rates and design pressures for each pour. He shall include a superstructure placing diagram showing the concrete placing sequence and construction joint locations.

6.1.2.7. Settlements
The Contractor shall show anticipated total settlements of falsework and forms. Include falsework footing settlement and joint take-up. He shall design for anticipated settlements not to exceed 25 mm. The falsework shall be designed and constructed to elevations that include anticipated settlement during concrete placement and required camber to compensate for member deflections during construction.

6.1.2.8. Traffic
Where openings through the falsework are required to permit the passage of public traffic, the location of all such openings shall be shown, including horizontal and vertical clearances and the location of temporary railing. For falsework over traffic, the sequence of falsework erection and removal shall be shown.

Separate falsework drawings shall be submitted for each structure, except for identical structures with identical falsework design and details. The construction of any unit of falsework shall not be started until the drawings for that unit are reviewed and approved.

6.1.3. Requirements
The temporary works must be designed so as to support all loads imposed and to provide the necessary rigidity to enable the production of the final structure.

The design of temporary works shall conform to (MA-100-D-V1/2 & V2/2) or the Guide Design Specifications for Bridge Temporary Works.

When using manufactured devices, the design shall not result in loads on such devices in excess of the strength load recommended by their manufacturer.

For equipment where the rated capacity is determined by load testing, the design load shall be as stated in the generally accepted design code or specification for such work.
The load rating used for special equipment, such as access scaffolding, may be under the jurisdiction of local regulations. However, in no case shall the rating exceed eighty percent (80%) of maximum load sustained during load testing of the equipment.

When required or specified in the contract documents, the design and the drawings shall be prepared and signed by a Professional Engineer.

Temporary works shall be constructed in agreement with the approved working drawings. The contractor shall verify that the quality of the materials and workmanship employed are consistent with that assumed in the design.

6.2. Forms and Falsework

6.2.1. Falsework Materials

6.2.1.1. General

Materials to be used may be new or used, manufactured components, or a combination of these materials in falsework construction. Concrete, reinforcing steel and structural steel to be used shall be conforming to the following Sections.

- Concrete Structural (Class A) Section 10
- Reinforcing Steel Section 11
- Steel Structural Section 13

If directed, material certifications for new materials should be supplied. Concrete tests should be performed as described in Section 10, "Concrete Structures". All salvaged and used material and manufactured components are subject to approval.

6.2.1.2. Salvaged Steel

Used structural steel satisfying ASTM A6 criteria for surface imperfections may be used in Falsework construction at the allowable working stresses for new material if the grade of steel can be identified. Unidentified steel shall not be permitted.

6.2.1.3. Timber


6.2.1.4. Used lumber

Used lumber of known species may be used in falsework construction under the following conditions:

If the grade is known and the lumber is in good condition, the allowable stresses shall not exceed those for new lumber of the same grade,

If the grade is unknown, it shall not be permitted, unless its grade is established by appropriate standard tests.

6.2.1.5. Manufactured components

Manufactured components of the following proprietary product classes may be used:
Section 6: Temporary Structures

Forms and Falsework

- Vertical shoring systems including tubular welded frame shoring, tube and coupler shoring, and components thereof,
- Manufactured assemblies including single-post shores, brackets, jacks, joists, clamps, and similar devices manufactured for commercial use.

6.2.2. Forms Materials

6.2.2.1. General

Forms used for concrete shall be mortar-tight, true to the dimensions, lines, and grades of the structure, and of sufficient strength to prevent appreciable deflection during concrete placement. Unless otherwise specified, the permissible variation from plan should be complying with the values in Table 6.1 below.

<table>
<thead>
<tr>
<th>Item</th>
<th>Tolerance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation from plan line</td>
<td>±25</td>
</tr>
<tr>
<td>Cross-sectional dimensions of columns, piers and beams, slabs, and walls</td>
<td>+25 -12</td>
</tr>
<tr>
<td>Bridges deck thickness</td>
<td>+12 - 6</td>
</tr>
</tbody>
</table>

Note (1): Variations are to be compared with dimensions shown on the Plans or directed by the Engineer.

Note (2): Tolerance measurement is perpendicular to the plan line or surface. This tolerance includes measurement of alignment, plumb, grade and level. Plumb (or batter) of retaining walls will be inspected both before and after backfilling.

6.2.2.2. Sheathing

For exposed concrete surfaces, materials fulfilling the SASO standard in Plywood or U.S. Product Standard PS 1 for Exterior B-B (Concrete Form) Class I Plywood, which produces a smooth and uniform concrete surface shall be used. Form panels to be used should be in good condition free of defects on exposed surfaces. If form panel material other than plywood is used, it shall have flexural strength, modulus of elasticity, and other physical properties equal to or greater than the physical properties for the type of plywood specified.

6.2.2.3. Structural Support

Materials for structural support of forms shall comply with the materials requirements for falsework. Vertical side forms, wall forms and column forms and related studs, walers, etc. are considered formwork or structural support for formwork.

6.2.2.4. Prefabricated Formwork

If prefabricated formwork is to be used, shop drawings under Article 6.1.2 and technical data substantiating load-carrying capacity and detailing application instructions and limitations of use shall be furnished. Prefabricated products shall be used according to manufacturer’s recommendations.

6.2.2.5. Stay-in-Place Steel Deck Forms

Stay-in-place steel deck forms may be used only when permitted in the contract documents or approved by the Engineer.
If used, the prefabricated formwork requirements shall be met. Design calculations with shop drawings shall be furnished. Stay-in-place steel deck forms and supports shall be fabricated from steel conforming to SASO standards or to ASTM A 653, Grades 275 and 340, having a coating class of G165 according to ASTM A 525.

**6.2.2.6. Stay-in-Place Prestressed Concrete Deck Forms**

Stay-in-place prestressed concrete deck forms may be used only when permitted in the contract documents or approved by the Engineer.

If used, the prefabricated formwork requirements shall be met. Complete deck design calculations with the shop drawings shall be furnished. And stay-in-place deck forms shall be fabricated according to Section 13 “Steel Structures”.

**6.2.3. Falsework Design and Construction**

**6.2.3.1. Design Loads**

The design load for falsework shall consist of the sum of dead and live vertical load, and any horizontal loads.

1. **Vertical loads:**

**Dead load:** As a minimum, dead load shall include the weight of the falsework and all construction material to be supported. The combined unit weight of concrete, reinforcing and prestressing steel and form shall be assumed to not be less than 26 kN/m³ for normal weight concrete or 21 kN/m³ for light weight concrete that is supported.

**Live load:** Live load shall consist of actual weight of any equipment to be supported applied as concentrated loads at the points of contact and a uniform load of not less than 1 kN/m² applied over the area supported, plus 1.1 kN/m applied at the out side edge of deck overhangs.

**Redistributed Prestress load:** For post-tensioned structures, the falsework shall also be designed to support any increase or distribution of loads caused by prestressing of the structure.

**Impact:** When impact can occur, the design load causing the impact on steel members and manufactured components shall be increased by at least thirty percent (30%).

**Minimum Vertical Load:** The total vertical design load to be used shall not be less than 5 kN/m². The total vertical design load for falsework is the sum of dead and live vertical loads.

2. **Horizontal loads**

An assumed horizontal design load on falsework structures shall be used to verify lateral stability. This assumed horizontal load shall be the sum of the horizontal loads due to equipments, construction sequence, including unbalanced hydrostatic forces from fluid concrete, stream flow when applicable, and an allowance for wind.

The Falsework shall be designed with sufficient rigidity to resist the assumed horizontal load without vertical dead load.

**a. Wind Load**

The minimum requirements for wind loads are to be used if there is no site specific wind study as shown in Table 6.2. However, if such study exists, the wind loads that
produce more severe effects of either the site specific wind study or the minimum requirements shall be used.

Table 6.2: Design Wind Pressure - Heavy Duty Steel Shoring

<table>
<thead>
<tr>
<th>Height Zone above Ground in (m)</th>
<th>Wind Pressure Value (kN/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjacent To Traffic</td>
</tr>
<tr>
<td>0</td>
<td>0.96</td>
</tr>
<tr>
<td>9 -15</td>
<td>1.2</td>
</tr>
<tr>
<td>15 – 30</td>
<td>1.45</td>
</tr>
<tr>
<td>Over 30</td>
<td>1.675</td>
</tr>
</tbody>
</table>

The minimum wind allowance on all other types of falsework, including falsework supported on heavy-duty shoring, is the sum of the products of the wind impact area and the applicable wind pressure value for each height zone. The wind impact area is the gross projected area of the falsework and unrestrained portion of the permanent structure, excluding the areas between falsework posts or towers where diagonal bracing is not used. Unless otherwise specified the design wind pressures in Table 6.3 shall be used.

Table 6.3: Design Wind Pressure - Other Types of Falsework

<table>
<thead>
<tr>
<th>Height Zone above Ground (m)</th>
<th>Wind Pressure Value (kN/m²) for Members Over and Bents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adjacent To Traffic Openings</td>
</tr>
<tr>
<td>0</td>
<td>0.320 Q (1)</td>
</tr>
<tr>
<td>9 -15</td>
<td>0.400 Q</td>
</tr>
<tr>
<td>15 – 30</td>
<td>0.480 Q</td>
</tr>
<tr>
<td>Over 30</td>
<td>0.560 Q</td>
</tr>
</tbody>
</table>

Note(1): \( Q = 0.3 + 0.2W \), but not more than 3. Where \( W \) is the width of the falsework system in meters measured in the direction of the wind force being considered.

b. Stream flow

When falsework supports are placed in flowing water, water pressure shall be determined by the following formula:

\[ P_w = 514 \times C_D \times V^2 \]

Where \( P_w \) is the pressure of flowing water in N/m², \( V \) is the water velocity in (m/s), and \( C_D \) is the drag coefficient having the following values:

- 0.7 for a semicircular nosed pier,
- 1.4 for a square ended pier,
- 1.4 for debris lodged against a pier,
- 0.8 for a wedged nosed pier with nose angle 90° or less.

Scour depths shall be investigated if directed by the Engineer.

c. Lateral fluid pressure

For concrete with retarding admixture, fly ash, or other pozzolan replacement for cement, forms, form ties, and bracing shall be designed for a lateral fluid pressure based on concrete with a density of 24 kN/m³. For concrete containing no pozzolans or admixtures, which affect the time to initial set, the lateral fluid pressure based on
concrete temperature and rate of placement shall be determined according to ACI Standard 347R, “Guide for Formwork for Concrete”.

d. Minimum Horizontal Load

However, in no case shall the horizontal load to be resisted in any direction be less than two percent (2%) of the total dead load.

3. Load Combinations

Falsework should be designed for the load combinations shown in Table 6.4.

Table 6.4: Load combinations

<table>
<thead>
<tr>
<th>Load combinations</th>
<th>Basic Allowable Stress or Load (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL+DP+LL+I+H</td>
<td>100</td>
</tr>
<tr>
<td>DL+DP+PS+H</td>
<td>100</td>
</tr>
<tr>
<td>DL+DP+LL+I+W+SF</td>
<td>133</td>
</tr>
<tr>
<td>DL+DP+LL+PD+W+SF</td>
<td>133</td>
</tr>
</tbody>
</table>

where:

- DL = design dead load,
- DP = dead load of support permanent structure,
- LL = construction live load,
- I = impact load,
- H = minimum horizontal design load,
- PS = redistributed prestress load,
- W = wind load,
- SF = stream flow load.

4. Slenderness

For compression members, the slenderness ratio, L/r, should be limited to the following values:

- Main load-carrying members:
  - 145 for steel,
  - 80 for aluminum.
- Bracing members:
  - 160 for steel,
  - 150 for aluminum.

Also for tension members use 190 and 240 for main bracing respectively.

Where:

- L = Unsupported length.
- r = Radius of gyration of the member.

6.2.3.2. Allowable Design Stresses

Certified data from authorized agency shall be accepted after review and approval from the Engineer.

The maximum allowable design stresses listed in this section are based on the use of undamaged, high-quality material. If lesser quality material is used, allowable stresses shall be reduced significantly.

The maximum allowable stresses in the design of falsework shall be as follows:
1. Timber

The different allowable stresses in timber are listed in Table 6.5.

Table 6.5: Allowable design limitations in timber

<table>
<thead>
<tr>
<th>Type of stress or characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression perpendicular to the grain</td>
<td>3.1 MPa</td>
</tr>
<tr>
<td>Compression parallel to the grain</td>
<td>$\frac{3309}{(L/d)^2}$ MPa</td>
</tr>
<tr>
<td>Flexural stress$^{(1)}$</td>
<td>12.4 MPa</td>
</tr>
<tr>
<td>Horizontal shear</td>
<td>1.3 MPa</td>
</tr>
<tr>
<td>Axial tension</td>
<td>8.3 MPa</td>
</tr>
<tr>
<td>Modulus of elasticity (E)</td>
<td>11.7 GPa</td>
</tr>
<tr>
<td>Maximum axial loading on timber piles</td>
<td>400 kN</td>
</tr>
</tbody>
</table>

Note(1): Not to exceed 11 MPa

Where:
- $L$ = Unsupported length
- $d$ = Least dimension of a square or rectangular column or the width of a square of equivalent cross-sectional area for round columns

Note(2): Reduced to 10 MPa for members with a nominal depth of 200 millimeters or less.

Timber connections shall be designed according to the stresses allowed in the generally accepted design code or specification for such work except:

1. Reductions in allowable loads required therein for high moisture condition of the lumber and service conditions do not apply.
2. The value of seventy-five percent (75%) of the tabulated design value shall be used as the design value of bolts in two member connections (single shear).

2. Steel

The design stresses, for identified grades of steel, shall not exceed the values specified in SASO standard or the AISC Manual of Steel Construction. Or corresponding national agency from the country of the producer/ and or the supplier.

For all grades of steel, the value of design stresses shall not exceed the value indicated in Table 6.6.

Table 6.6: Allowable stresses in steel

<table>
<thead>
<tr>
<th>Type of stress or characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial and flexural tension</td>
<td>150 MPa</td>
</tr>
<tr>
<td>Axial compression$^{(1)}$</td>
<td>$110 - 0.0026(L/R)^2$ MPa</td>
</tr>
<tr>
<td>Web crippling for rolled shapes</td>
<td>185 MPa</td>
</tr>
<tr>
<td>Shear on web gross section for rolled shapes</td>
<td>100 MPa</td>
</tr>
<tr>
<td>Flexural compression$^{(2)}$ (for all grades of steel)</td>
<td>$82750/[(L\times d)/(b\times t)]$ MPa</td>
</tr>
<tr>
<td>Modulus of elasticity (E)</td>
<td>210 GPa</td>
</tr>
</tbody>
</table>

Note(1): $(L/R)$ shall not exceed 120.
- $L$ = Unsupported length.
- $r$ = Radius of gyration of the member.

Note(2): Not to exceed 150 MPa for unidentified steel or steel conforming to ASTM A 36. Not to exceed $(0.6 \times f_y)$ for other identified steel.

Where:
- $L$ = Unsupported length.
- $d$ = Least dimension of a square or rectangular column or the width of a square of equivalent cross-sectional area for round columns or the depth of beams.
\[ b = \text{Width of the compression flange.} \]
\[ t = \text{Thickness of the compression flange.} \]
\[ F_y = \text{Specified minimum yield stress for the grade of steel used.} \]

### 3. Other requirements

The falsework design calculations shall show:

1. The stresses and deflections in load supporting members.
2. The anticipated total settlements of falsework and forms, which shall not exceed 25 mm, including falsework footing settlement and joint take-up.
3. The details of falsework supporting deck slabs and overhangs on girder bridges so there is no differential settlement between the girders and the deck forms during placement of deck concrete.
4. The elevations of falsework including anticipated settlement during concrete placement and required camber to compensate for member deflections during construction.
5. The details of strengthening and protecting falsework over or adjacent to roadways and railroads during each phase of erection and removal.
6. The intended steel erection procedures with calculations in sufficient detail to substantiate that the girder geometry will be correct.

The falsework spans supporting T-beam girder bridges shall be limited to 4.3 meters plus 8.5 times the overall depth of T-beam girder.

### 4. Manufactured Assemblies

For jacks, brackets, columns, joists and other manufactured devices, the ultimate load carrying capacity of the assembly shall not exceed the manufacturer's recommendations or forty percent (40%) of the ultimate load carrying capacity that has been determined by actual testing.

The contractor shall furnish catalog or equivalent data showing the manufacturer's recommendations or perform tests, as necessary, to demonstrate the adequacy of any manufactured device proposed for use. The contractor shall not substitute other manufacturer's components unless the manufacturer's data encompasses such substitutions or field tests reaffirm the integrity of the system.

If a component of the falsework system consists of a steel frame tower exceeding 2 or more tiers high, the differential leg loading within the steel tower unit shall not exceed 4 to 1. An exception may be approved if the manufacturer of the steel frame certifies, based on manufacturer's tests, that the proposed differential loadings are not detrimental to the safe load carrying capacity of the steel frame.

### 6.2.3.3. Foundation

Falsework shall be founded on a solid footing safe against undermining, protected from softening, and capable of supporting the loads imposed on it. When requested by the Engineer, the contractor shall demonstrate by suitable load tests that the soil bearing values assumed for the design of the falsework footing shall not exceed the supporting capacity of the soil (The maximum allowable bearing capacity for foundation material, other than rock, is 190 kN/m²).

The contractor shall include in working drawing a drainage plan or description of how foundations will be protected from saturation, erosion, and/or scour.
Falsework which can not be founded on a satisfactory footing shall be supported on pilling which shall be spaced, driven, and removed in an approved manner.

The contractor shall verify in field all ground elevations at proposed foundation locations before design.

The edge of footings shall not be located closer than 300 mm from the intersection of the bench and the top of the slope. Unless the excavation for footings is adequately supported by shoring, the edge of the footings shall not be closer than 1.2 m or the depth of excavation, whichever is greater, from the edge of the excavation.

When falsework is supported by footings placed on paved, well-compacted slopes of berm fills, the falsework shall not be strutted to columns unless the column is founded on rock or supported by piling.

When individual steel towers have maximum leg loads exceeding 130 kN, provide for uniform settlement under all legs or each tower under all loading conditions.

The foundation shall be protected from adverse effects for the duration of its use. Advise the Contractor of actions that will be taken to protect the foundation.

6.2.3.4. Deflection

For cast-in-place concrete structures, limit the calculated deflections of falsework and formwork members as follows:

1. Falsework members vertical deflection: 1/360 of the span under the dead load of the concrete only, regardless of the fact that deflection may be compensated for by camber strips.
2. Formwork (other than sheathing): 1/360 of the span under the dead load of the concrete only or the lateral pressure of fluid concrete only.
3. Formwork (sheathing): 1/270 of the center-to-center distance between studs, joists, form stiffeners, form fasteners, or wales.

6.2.3.5. Clearance

The minimum dimensions of clear horizontal opening for roadways which are to remain open to traffic during construction shall be at least 1.5 meter greater than the width of the approach traveled way, between barriers, and 5.50 meters high, as the minimum vertical clearance over Primary, Secondary and Feeder Roads.

6.2.3.6. Construction

Falsework shall be constructed and set to grades which allow for its anticipated settlement and deflection, and for the vertical alignment and camber indicated on the plans or ordered by the Engineer for the permanent structure. Camber shall be provided for the falsework to account for the Falsework deflection and anticipated structure deflection. Variable depth camber strips shall be used between falsework beams and soffit forms to accomplish this when directed by the Engineer.

Suitable screw jacks, pairs of wedges or other devices shall be used at each post to adjust falsework to grade, to permit minor adjustments during the placement of concrete or structural steel shall observed settlements deviate from those anticipated, and to allow for the gradual release of the falsework. Telltale attached to the forms and extending to the ground, or other means, shall be provided by the Contractor for accurate measurement of falsework settlement during the placing and curing of the concrete.
Falsework or formwork for deck slabs on girder bridges shall be supported directly on the girders so that, there will be no appreciable differential settlement during placing of the concrete. Girders shall be braced and tied to resist any forces that would cause rotation or torsion in the girders, caused by the placing of concrete for diaphragms or deck. Welding of falsework support brackets or braces to structural steel members or reinforcing steel shall not be allowed unless specifically permitted.

Telltales shall be attached to soffit forms in enough systematically placed locations to be able to determine from the ground the total settlement of the structure while concrete is being placed.

Dead loads shall not be applied, other than forms and reinforcing steel, to any falsework until authorized.

If unanticipated events occur, concrete placement shall be discontinued and corrective actions shall be made to the settlements that cause a deviation of more than 10 mm from those shown on the falsework drawings. All unacceptable concrete shall be removed if corrective action is not taken before the initial set.

1. Falsework Over or Adjacent to Roadways and Railroads

Falsework shall be designed and constructed to be protected from vehicle impact. This includes falsework and formwork posts that support members crossing over a roadway or rail road and other falsework posts if they are located in the row of falsework posts nearest to the roadway or railroad and if the horizontal distance from the traffic side of the falsework to the edge of pavement or to a point 3 meters from the centerline of track is less than the total height of the falsework.

Additional features shall be provided to ensure that this falsework will remain stable if subjected to impact by vehicles. Vertical design loads shall be used for these falsework posts, columns, and towers (but not footings) that are greater than or equal to either of the following:

1. One hundred and fifty percent (150%) of the design load calculated but not including any increased or readjusted loads caused by prestressing forces
2. The increased or readjusted loads caused by prestressing forces

Temporary traffic barriers shall be installed before erecting falsework towers or columns adjacent to an open public roadway. The location of barriers shall be so placed that the Falsework footings or pile caps shall be at least 75 mm clear of concrete traffic barriers and all other falsework members are at least 300 mm clear. These barriers shall not be removed until approved Engineer.

The minimum section modulus about each axis of columns used in falsework shall be \(156 \times 10^3 \text{ mm}^3\) for steel columns and \(4 \times 10^3 \text{ mm}^3\) for timbers.

The base of each column or tower frame supporting falsework over or immediately adjacent to an open public road shall be mechanically connected to its supporting footing laterally restrained to resist a force of not less than 9 kN applied to the base of the column in any direction.

Such columns or frames shall be mechanically connected to the falsework cap or stringer to resist a horizontal force of not less than 4.5 kN in any direction.

The effects of frictional resistance shall be neglected.
Exterior girders, upon which overhanging bridge deck falsework brackets are hung, to the adjacent interior girders as necessary, shall be braced or tied to prevent rotation of exterior girders or overstressing the exterior girder web.

All exterior falsework stringers and stringers adjacent to the end of discontinuous caps shall be mechanically connected (the stringer or stringers over points of minimum vertical clearance and every 5th remaining stringer) to the falsework cap or framing.

Connections shall be installed before traffic is allowed to pass beneath the span. These connections shall be capable of resisting a load in any direction, including uplift on the stringer, of not less than 2.2 kN.

Falsework bents shall be sheathed within 6 meters of the centerline of a railroad track side in the area between 1 and 5 meters above the track on the side facing the track. Sheathing of plywood (not less than 16 mm thick) or lumber (not less than 25 mm nominal thickness) shall be constructed.

Bracing on such bents shall be provided adequately so that the bent resists the required assumed horizontal load or 22 kN, whichever is greater, without the aid of sheathing.

Minimum required vertical and horizontal clearances through falsework for roadways, railroads, pedestrians, and boats shall be provided.

2. Falsework for Steel Structures

1- Falsework design loads shall consist of the mass of structural steel, the load of supported erection equipment and all other loads supported by the falsework.

2- Falsework and forms for concrete supported on steel structures shall be designed so that loads are applied to girder webs within 150 mm of a flange or stiffener. The loads shall be distributed in a manner that does not produce local distortion of the web. Deck overhang forms that require holes to be drilled into the girder webs shall not be used.

3- Exterior girders supporting overhanging deck falsework brackets shall be strutted and tied to adjacent interior girders to prevent distortion and overstressing of the exterior girder web.

4- The loads to be applied on new or partially completed structures shall not exceed the load carrying capacity of any part of the structure.

5- Supporting falsework that will accommodate the proposed method of erection shall be built without overstressing the structural steel, as required, and will produce the required final structural geometry, intended continuity, and structural action.

6.2.4. Formwork Design and Construction

6.2.4.1. General

Formwork shall be of wood, steel, or other approved material and shall be mortar tight and of sufficient rigidity to prevent objectional distortion of the formed concrete surface due to pressure of the concrete and other loads incidental to the construction operations.

Forms for concrete surfaces exposed to view shall produce a smooth surface of uniform texture and color substantially equal to that which shall be obtained with the use of plywood conforming to the National Institute of Standards and Technology Product Standard PSI for Exterior B-B Class I Plywood. Panels lining such forms shall be arranged so that the joint lines form a symmetrical pattern conforming to the general
lines of the structure. The same type of form lining material shall be used through-out each element of a structure. Such forms shall be sufficiently rigid so that the undulation of the concrete surface shall not exceed 3 mm when checked with a 1.5 m long straightedge or template. All sharp corners shall be filleted with approximately 20 mm chamfer strips.

Concrete shall not be deposited in the form until all work connected with constructing the forms has been completed, all debris has been removed, all materials to be embedded in the concrete have been placed for the unit to be cast, and the Engineer has inspected and approved the forms and materials.

6.2.4.2. Design

The structural design of formwork shall conform to the ACI Standard, Recommended Practice for Concrete Formwork (ACI 347-78) or some other generally accepted and permitted standards. In selecting the hydrostatic pressure to be used in the design of forms, consideration shall be given to the maximum rate of concrete placement to be used, the effects of vibration, the temperature of the concrete and any expected use of set-retarding admixtures or pozzolanic materials in the concrete mix.

6.2.4.3. Construction

Forms shall be set and held true to the dimensions, lines and grades of the structure prior to and during the placement of concrete. Forms may be given a bevel or draft at projections, such as copings, to ensure easy removal. Prior to reuse, forms shall be cleaned, inspected for damage and, if necessary, repaired. When forms appear to be defective in any manner, either before or during the placement of concrete, the Engineer may order the work to be stopped until defects have been corrected.

Forms shall be treated with form oil or other approved release agent before the reinforcing steel is placed. Material which will adhere to or discolor the concrete shall not be used.

Except as provided herein, metal ties or anchorages within the form, shall be so constructed as to permit their removal to a depth of at least 25 mm from the face without injury to the concrete. Ordinary wire ties may be used only when the concrete will not be exposed to view and where the concrete will not come in contact with salts or sulfates. Such ties, upon removal of the forms, shall be cut back at least 6 mm from the face of the concrete with chisels or nippers; for fluid concrete, nippers shall be used. Fittings for metal ties shall be of such design that, upon their removal, the cavities shall be filled with cement mortar and the surface left sound, smooth, even, and uniform in color.

When epoxy–coated reinforcing steel is required, all metal ties, anchorages or spreaders which will remain in the concrete shall be of corrosion resistant material or coated with a dielectric material.

For narrow walls and columns, where the bottom of the form is inaccessible, an access opening shall be provided in the forms for cleaning out extraneous material immediately before placing the concrete.

6.2.4.4. Tube Forms

Tubes used as forms to produce voids in concrete slabs shall be properly designed and fabricated or otherwise treated to make the outside surface waterproof. Prior to concrete placement such tubes shall be protected from the water and stored and installed by methods the prevent distortion or damage. The ends of tubes forms shall be
covered with cap that shall be made mortar tight and waterproof. If wood or other material that expands when moist is used for capping tubes, premolded rubber joint filler 6 mm in thickness shall be used around the perimeter of the cap to permit expansion. A PVC vent tube shall be provided near each end of each tube. These vents shall be constructed to provide positive venting of the voids. After exterior form removal, the vent tube shall be trimmed to within 15 mm of the bottom surface of the finished concrete.

Anchors and ties for tube forms shall be adequate to prevent displacement of the tubes during concrete placements.

6.2.4.5. Stay-in-Place Forms

Stay-in-place deck soffit forms, such as corrugated metal or pre-cast concrete panels, may be used if shown on the plans or approved by the Engineer. Prior to the use of such forms the contractor shall provide a complete set of details to the Engineer for view and approval. The detailed plans for structures, unless otherwise noted, are dimensioned for the use of removable forms and any changes necessary to accommodate stay-in-place forms, if approved, shall be at the expense of the contractor.

6.2.5. Removal of Falsework and Forms

6.2.5.1. General

Falsework or forms shall not be removed without the approval of the Engineer. In the determination of the time for the removal of falsework and forms, consideration shall be given to the location and character of the structure, the weather, the materials used in the mix, and other condition influencing the early strength of the concrete.

Methods of removal likely to cause overstressing of the concrete or damage to its surface shall not be used. Supports shall be removed in such a manner as to permit the structure to uniformly and gradually take the stresses due to its own weight.

Any remedial treatment to surfaces shall be agreed with the Engineer following inspection after removing the formwork and shall be carried out without delay. Any concrete surface which has been treated before being inspected by the Engineer, shall be liable to rejection.

Defects that will need repair, when removal of entire defective portions is not directed by the Engineer, shall also include crazing, cracks, spalls, popouts, air bubbles, honeycomb, and holes left by rods and bolts; other surface deficiencies that penetrate to the reinforcement; fins and other objectionable projections on the surface, as determined by the Engineer; and stains and discolorations that cannot be removed by cleaning.

Falsework for arch bridges shall be removed uniformly and gradually. The removal shall begin at the crown and work toward the springing. The falsework for adjacent arch spans shall be removed simultaneously.

Forms used to support the deck of box girders and forms in hollow abutments or pieces may remain in place when no permanent access is available into the cells. Where it is intended to re-use formwork, it shall be thoroughly cleaned and made good to the satisfaction of the Engineer prior to re-use.

Forms that do not support the dead load of concrete members and forms for railings and barriers shall be removed 24 hours after the concrete is placed. Exposed concrete surfaces shall be protected from damage.
Forms and Falsework shall be removed and shall remain the property of the Contractor upon completion of their use. The area shall be restored to its original or planned condition and cleaned of all debris.

6.2.5.2. Time of Removal

The removal of forms and supports shall not be started before the periods indicated in Table 6.7 as follows.

<table>
<thead>
<tr>
<th>Structural member</th>
<th>Time of Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Forms and Falsework Supporting</td>
<td></td>
</tr>
<tr>
<td>Spans more than 4.3 m (Slab spans, pan girder, RCB decks, pier caps)</td>
<td>14 days</td>
</tr>
<tr>
<td>Spans of 4.3 m or less (Bridges decks on girders, RCB decks, diaphragms, pile bent pier caps)</td>
<td>10 days</td>
</tr>
<tr>
<td>2- Forms (Not supporting the dead weight of concrete)</td>
<td></td>
</tr>
<tr>
<td>Columns, walls, side forms for abutments and pier caps</td>
<td>24 hours</td>
</tr>
<tr>
<td>Railing and barriers</td>
<td>10 hours</td>
</tr>
</tbody>
</table>

Special notes on the plans relative to the removal of forms and falsework under arches, continuous spans, and other special structures shall have precedence over the above time limits for removal of forms and falsework.

Time of removal for supporting forms or falsework (except those for columns, walls, side forms for abutment, pier caps, railing and barriers) may be shortened at the discretion of the Engineer if the concrete has attained eighty percent (80%) of the specified strength.

In addition to the above requirements:

Forms shall not be removed until the concrete has sufficient strength to prevent damage to the surface.

Falsework for post-tensioned portions of structures shall not be released until the prestressing steel has been tensioned.

Falsework supporting any span of a continuous or rigid frame bridge shall not be released until the aforementioned requirements have been satisfied for all of the structural concrete in that span and in the adjacent portions of each adjoining span for a length equal to at least one-half the length of the span where falsework is to be released.

Unless otherwise specified or approved, falsework shall be released before the railings, copings or barriers are placed for all types of bridges. For arch bridges, the time of falsework release relative to the construction of elements of the bridge above the arch shall be as shown on the plans or directed by the Engineer.

6.2.5.3. Extent of Removal

All falsework and forms shall be removed except:
1- Portion of driven falsework piles more than 300 mm below subgrade within roadbeds, or 600 mm below the original ground or finished grade outside of roadbeds, or 600 mm below the established limits of any navigation channel.

2- Footing forms where their removal would cause danger to the safety of cofferdams or other work.

3- Forms from enclosed cell where access is not provided.

4- Deck forms in the cells of box girder bridges that do not interfere with the future installation of utilities.

6.3. **Cofferdams And Shoring**

6.3.1. **General**

Cofferdams are temporary structures constructed to:

1- Keep water and soil out of excavations in which bridge piers or other substructures are to be built.

2- Protect adjacent property and facilities during construction of the permanent work.

Usually, cofferdams are dewatered so that the substructures can be built under dry conditions. After the substructures have been completed, the cofferdams are removed.

Cofferdams shall be constructed to sufficient depths, generally well below the bottom of the excavation, and to sufficient heights to seal off all water. They shall be safely designed and constructed, and be made as watertight as is necessary for the proper performance of the work which must be done inside them. In general, interior dimensions of cofferdams shall be such as to give sufficient clearance for the construction of forms and the inspection of their exteriors, and to permit pumping from outside the forms. Cofferdams which are tilted or moved laterally during the process of sinking shall be righted, reset, or enlarged so as to provide the necessary clearance. This shall be solely at the expense of the contractor.

The contractor shall prevent the penetration of water so that footing concrete can be placed in the dry. If a seal is required the contractor shall determine the depth of seal, and the required cure time. After the seal has cured, the cofferdams shall then be pumped out and the balance of the masonry placed in the dry. When weighted cofferdams are employed and the weight is utilized to partially overcome the hydrostatic pressure acting against the bottom of the foundation seal, special anchorage such as dowels or keys shall be provided to transfer the entire weight of the cofferdams onto the foundation seal. During the placing and curing of a foundation seal, the elevation of the water inside the cofferdams shall be controlled to prevent any flow through the seal, and if the cofferdam is to remain in place, it shall be vented or ported at or below low water level.

Shoring shall be adequate to support all loads imposed and shall comply with any applicable safety regulations.

6.3.2. **Protection of Concrete**

Cofferdams shall be constructed to protect fluid concrete against damage from a sudden rising of the stream and to prevent damage to the foundation by erosion. No struts or braces shall be used in cofferdams or shoring system in such a way as to extend into or through the permanent work, without written permission from the Engineer.
6.3.3. Removal

Unless otherwise provided or approved, cofferdams, and shoring with all sheathing and bracing shall be removed after the completion of the substructure, with care being taken not to disturb or otherwise injure the finished work.

6.4. Temporary Water Control Systems

6.4.1. General

This work consists of dikes, ditches, bypass channels, flumes and other surface water division works, cut-off walls and pumping system, including wellpoint and deep well system, used to prevent water from entering excavations for structures.

6.4.2. Working drawings

The working drawing for temporary water control systems, when required, shall include the details of design and the equipment, operating procedures. The location of point or points has to be mentioned in the details. The design and operation shall conform to all applicable water pollution control requirements.

6.4.3. Operation

Pumping from the interior of any foundation enclosure shall be done in such a manner as to preclude the possibility of the movement of water through any fresh concrete. No pumping will be permitted during the placing of concrete, or a period of at least 24 hours thereafter, unless it is done from a suitable sump separated from the concrete works by a watertight wall or other effective means subject to the approval of the Engineer.

Pumping to unwater a sealed cofferdam shall not commence until the seal has set sufficiently to withstand the hydrostatic pressure.

Pumping from wellpoints or deep wells shall be regulated so as to avoid damage by subsidence to adjacent property.

6.5. Temporary Bridges

6.5.1. General

Temporary bridges include detour bridges for use by the public, haul road bridges and other structures, such as conveyor bridges, used by the contractor. Temporary bridges shall be constructed, maintained and removed in a manner that will not endanger the work or the public.

6.5.2. Detour Bridges

The design shall provide the clearances, alignment, load capacity and other design parameters specified or approved in the contract documents. The design shall conform to the (MA-100-D-V1/2 & V2/2) (or to these specifications). If design live loads are not otherwise specified in the contract document, the design load for permanent bridges may be used. The working drawings and design calculations shall be signed by a professional Engineer.
6.5.3. Haul Bridges

When Haul road bridges or other bridges which are not for public use are proposed for construction over any right-of-way which is open to the public or over any rail-road, working drawings showing complete design and full details, including the maximum loads to be carried shall be submitted to the Engineer for approval. Such drawings shall be signed by Professional Engineer. The design shall conform to (MA-100-D-V1/2 & V2/2) when applicable or to other appropriate standards.

6.5.4. Maintenance

The maintenance of Temporary bridges for which working drawings are required shall include their replacement in case of partial or complete failure. The Ministry reserves the full rights, in case of the Contractor's delay or inadequate progress in making repairs and replacement, to furnish such labor, materials, and supervisions of the work as may be necessary to restore the structure to a proper condition suitable for movement of traffic. The entire expense of such restoration and repairs shall be considered a part of the cost of the temporary structure and where such expenditures are incurred by the Ministry they shall be charged to the contractor.

6.6. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and for work acceptance, Contractor shall apply quality control for temporary structures work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in the special specifications and client’s specifications or general specifications and other contract documents.

The Ministry shall apply quality assurance and verify the Contractor quality control procedures either through direct supervision or by carrying out neutrally quality assurance procedures using test on representative samples and in adequate numbers to judge about the quality level and accept or reject the executed works according to the principles detailed and test related to each element.

6.6.1. Quality Control

For temporary structure work acceptance, the design and all plans should be checked and insure that the quality of the materials are satisfying the quality requirements which mention in article 6.2, 6.3, 6.4, and 6.5 from this general specifications.

6.6.2. Quality Assurance:

Ministry, at any time, has the right request the design and plans to assure the quality of works and to insure that the materials are satisfying the specification and the test stipulated in the article 6.2 for forms and falsework, and article 6.3 for cofferdams and shoring, and article 6.4 for temporary water control system, and section 6.5 for temporary bridges.
6.7. Measurement and Payment

Unless otherwise provided, payment for temporary works shall be considered to be included in the payment for the various items of work for which they are used and no separate payment will be made therefore.

When an item for concrete seals for cofferdams is included in the bid schedule, such concrete will be measured and paid for as provided in Section 10, "Concrete Structures" in these Specifications.

When an Item or Items for Temporary bridges, cofferdams, shoring system or water control system is included in the bid schedule, payment shall be the lump sum bid for each such structure or system which is listed on the bid schedule and which is constructed and removed in accordance with the contractor requirements. Such payment includes full compensation for all costs involved with the furnishing of all materials and the construction, maintenance, and removal of such temporary works.

Payment will be made under one or more of the items in Table 6.8. And Table 6.9 show the quality control requirements for temporary structures.

Table 6.8: Temporary Works Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1</td>
<td>All temporary work</td>
<td>included in the bid schedule</td>
</tr>
</tbody>
</table>

Table 6.9: Quality Control Requirements For Temporary Structures

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falsework</td>
<td>Falsework over or adjacent to roadways</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>Each</td>
<td>Article 6.2.3.6.1</td>
</tr>
<tr>
<td>Falsework for steel structures</td>
<td>Falsework for steel structures</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>Each</td>
<td>Article 6.2.3.6.2</td>
</tr>
<tr>
<td></td>
<td>Tim of removal</td>
<td>Number of days</td>
<td>In situ</td>
<td>__________</td>
<td>Table 6.7</td>
</tr>
<tr>
<td>Cofferdams and Shoring</td>
<td>Shoring shall be adequate to support all loads imposed and shall comply with any applicable safety regulations</td>
<td>Visual inspection and measurement and conformity</td>
<td>In situ</td>
<td>Each</td>
<td>Article 6.3.1</td>
</tr>
<tr>
<td>Temporary Water Control Systems</td>
<td>Operation and timing</td>
<td>Observation and timing</td>
<td>In situ</td>
<td>Each</td>
<td>Article 6.4.3</td>
</tr>
</tbody>
</table>
6.8. References

National Forest Products Association in the U.S. (NDS ANSI/AF&PA NDS); 2005


AASHTO LRFD Bridges Construction Specifications -2004. Sec. 3

AASHTO LRFD Bridges Construction Specifications – 2008 interim.


SECTION 7. PILING AND DRILLED
SHAFTS CONSTRUCTION

7.1. Description

This work shall consist of:

- Furnishing all labor, materials, equipments and services necessary to perform all operations to complete a drilled shaft installation in accordance with these Specifications and the details and dimensions shown on the plans.
- Constructing drilled shafts including the furnishing and placing of reinforcing steel and concrete, all in accordance with the contract documents.
- Furnishing and driving foundation piles of the type and dimensions designated in the contract documents, including cutting off or building up foundation piles when required.
- Providing, when required, test piles and performing the requisite loading tests.

Piling shall conform to and be installed in accordance with these Specifications; moreover, the piling shall be installed and conform to the location, elevation, penetration, and the required nominal resistance shown in the contract documents or as directed by the Engineer.

Except when test of driven piles are required, the Contractor shall furnish the piles in accordance with the dimensions shown in the contract documents. When test piles are required, the production pile lengths shown in the contract documents shall be used for estimating purposes only and the actual lengths to be furnished for production piles shall be determined by the Engineer after the test piles have been driven and tested. The lengths given in the order list provided by the Engineer shall include only the lengths anticipated for use in the completed structure.

7.2. Submittals

7.2.1. Contractor Qualifications and Equipment Adequacy

The required contractor's qualifications are as follows:

1- The Contractor shall have a minimum of 3 years experience in constructing shaft foundations of similar size, depth and site conditions within the past 5 years. Prior to the construction of the shaft and driven piles, construction the Contractor shall submit written documentation of the three years of experience to the Engineer for verification and acceptance. The submittal shall include at least three projects on which the Contractor has previously been engaged in shaft and driven piles construction with satisfactory results. A brief description of each project and the owner's contact person's name and current phone number shall be included for each project listed in the experience documentation.

2- On-site supervisors shall have a minimum of two years of experience in constructing shaft and driven pile foundations. Drill operators and driving equipment operators shall have a minimum of one year of experience. Prior to the start of work, the Contractor shall submit a list identifying the on-site supervisors
and operators who will be assigned on the project. The list shall contain a summary of each individual’s experience.

3- The Engineer will approve or reject the Contractor's qualifications and field personnel within 10 working days after receipt of the submission. Work shall not be started until the Contractor's qualifications are approved by the Engineer. The Engineer may suspend the construction if the Contractor substitutes unqualified personnel. The Contractor shall be fully liable for the additional costs resulting from the suspension of work, and no adjustments in contract time resulting from the suspension of work will be allowed.

4- A pre-construction meeting shall be held with the Contractor and Sub-Contractor (if applicable) prior to the onset of shaft construction to discuss pertinent construction and inspection procedures. This conference will be scheduled by the Engineer after the Contractor's submittals are approved by the Engineer.

7.2.2. Working Drawings
The Contractor shall submit to the Engineer for review and approval an installation plan for the construction of drilled shafts and/or driven piles. The submittal shall include the following:

- List of proposed equipment to be used including driving equipments, cranes, drills, augers, bailing buckets, final cleaning equipment, desanding equipment, slurry pumps, sampling equipment, tremies or concrete pumps, casings (including: casing dimensions, material and splice details), etc.
- Details of overall construction operation sequence and the sequence of shaft construction in bents or groups.
- Details of shaft excavation methods and procedures for maintaining correct horizontal and vertical alignment of the excavation.
- When mineral slurry is required, details of the proposed method to mix, circulate, desand, and disposal of the slurry must be provided.
- Details of methods to clean the shaft excavation including the bottom of the shaft.
- Details of reinforcement placement including support, centralization and alignment methods.
- Details of concrete placement, curing and protection that demonstrate the contractor's ability to perform concrete placement in the required time.
- Other information shown on the plans or requested by the Engineer.
- Concrete mixes and mitigation of possible slump loss during placement at the site.
- Pile dimensions, materials, tendon arrangement, and prestressing forces proposed for use, and any addition or rearrangement of reinforcing steel from that shown in the contract documents. Construction of the piles shall not begin until the Engineer has approved the drawings.

Acceptance of the Contractor's plan, personnel, and trial shafts and/or driven piles does not relieve the Contractor of the responsibility for results obtained by use of these drawings or any of the Contractor’s other responsibilities under the contract documents.
7.3. Materials

7.3.1. Driven Piles
Production of piles shall be in accordance with Prestressed Concrete Institute (PCI) MNL-116, Manual for Quality Control for Plants and Production of Structural Precast Concrete Products.

7.3.1.1. Forms
Forms for prestressed concrete piles shall conform to the general requirements for concrete form work as provided in PCI MNL-116, Manual for Quality Control for Plants and Production of Structural Precast Concrete Products.

7.3.1.2. Casting
Concrete shall be cast continuously within three days after pretensioning steel; however, concrete shall not be cast in forms until placement of reinforcement and anchorages have been inspected and approved by the pile Manufacturer's quality control representative. Each pile shall have dense concrete, straight smooth surfaces, and reinforcement retained in its proper position during fabrication. Unless self-consolidating concrete is used, the concrete shall be compacted by vibrating with a vibrator head smaller than the minimum distance between the pretensioning steel. Ensure that pile end surfaces are perpendicular to the longitudinal axis of the pile.

7.3.1.3. Finish
Finish of piles shall be in accordance with PCI MNL-116, "Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products". Standard finish shall be that the formed sides are reasonably smooth from casting against approved forms. Standard finish of the top shall be a float finish with edges tooled.

7.3.1.4. Curing and Protection
Curing of piles shall be in accordance with PCI MNL-116, "Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products." Piles shall be cured using moist curing or accelerated steam curing.

No pile shall be driven until it is sufficiently cured so as to resist handling and driving stresses without damage.

In cold weather, an extended curing period may be required, as specified in the contract documents. Concrete shall be protected from freezing until the compressive strength reaches at least 0.8 $f'c$.

7.3.1.5. Prestressing
Prestressing of piles shall be in accordance with PCI MNL-116, "Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products".

7.3.1.6. Storage and Handling
Handling, storing, and transporting prestressed concrete piles shall be done in such a manner to avoid excessive bending stresses, cracking, spalling, or other damages.
7.3.2. Drilled Shafts

7.3.2.1. Concrete

Concrete shall conform to the requirement of Section 10, "Concrete Structures" and unless another class shown in the plans or specified, concrete shall be Class A excepting the maximum nominal aggregate size to 19 mm shall be used. When concrete placed under water or slurry, cement content shall be increased by at least ten percent (10%).

As per the site condition requirements, the admixtures in the concrete shall be adjusted so as to ensure workability and slump values of concrete which shall be at least 150 mm at the start of placement, and at least 100 mm at the completion of placement and casing/reinforcement alignment. The temperature of concrete shall not exceed thirty-five degree Celsius (35°C) during placement.

7.3.2.2. Reinforcing Steel

Reinforcing steel shall conform to the requirement of Section 11, "Reinforcing Steel".

7.3.2.3. Casings

Casings which are required to be incorporated as part of the permanent work shall conform to the requirements of Section 13, "Steel Structures". Steel shall conform to AASHTO M 183 (ASTM A 36), AASHTO M 270 (ASTM A 709) Grade 36, or ASTM A 252, Grade 2 or 3 unless otherwise specified.

Unless otherwise specified, welding of permanent exterior casings shall fulfill the requirements of Section 13, "Steel Structures". All the diameters shown on the plans denote the outside diameters.

All exterior steel casings shall be strong enough to withstand handling and driving stresses, and shall withstand the pressures imparted by concrete and the surrounding earth.

All permanent casings shall be locally available as per the required dimensions.

Permanent interior casings shall withstand the pressure of the concrete and it shall be round corrugated galvanized steel pipe with 75×25 mm corrugations meeting AASHTO M36 specifications, and of sufficient gauge to maintain a round shape.

The outside diameter of casing shall not be less than the specified diameter of the shaft. The inside diameter of the casing shall not be greater than the specified diameter of the shaft plus 150 mm unless otherwise approved by the Engineer. Where the minimum thickness of the casing is specified in the Plans, it is specified to satisfy structural design requirements only. The Contractor shall increase the casing thickness as necessary to satisfy the casing strength requirements for handling and driving stresses. Temporary casings may be corrugated and non-watertight if conditions permit.

7.3.2.4. Slurry

Slurry used in the drilling process shall be mineral slurry. The slurry shall have both a mineral grain size that will remain in suspension and sufficient viscosity and gel characteristics to transport excavated material to a suitable screening system. The…

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1 Classes of Concrete are detailed in Section 7, “Concrete Structures”.
percentage and specific gravity of the material used to make the suspension shall be sufficient to maintain the stability of the excavation and to allow proper concrete placement. The level of the slurry shall be maintained at a height sufficient to prevent caving of the hole.

The mineral slurry shall be premixed thoroughly with clean fresh water and adequate time allotted for hydration prior to introduction into the shaft excavation. Adequate slurry tanks will be required when specified. No excavated slurry pits will be allowed when slurry tanks are required on the project; unless written permission is granted by the Engineer. Adequate desanding equipment will be required when specified, and such steps shall be taken to prevent the slurry from "setting up" in the shaft excavation, such as, agitation, circulation, and adjusting the properties of the slurry.

Control tests using suitable apparatus shall be carried out by the Contractor on the mineral slurry to determine density, viscosity, and pH. An acceptable range of values for those physical properties is shown in Table 7.1 for Slurry and Table 7.2 for Polymer Slurry.

<table>
<thead>
<tr>
<th>Property</th>
<th>At Time of Slurry Introduction</th>
<th>At Time of Concreting (In Hole)</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (kN/m³)</td>
<td>10.3-11</td>
<td>10.3-12</td>
<td>Density Balance</td>
</tr>
<tr>
<td>Viscosity (sec/liter)</td>
<td>30-48</td>
<td>30-48</td>
<td>Marsh cone</td>
</tr>
<tr>
<td>pH</td>
<td>8-11</td>
<td>8-11</td>
<td>pH paper or meter</td>
</tr>
</tbody>
</table>

Table 7.2: Acceptable Range of Values for Polymer Slurry

<table>
<thead>
<tr>
<th>Property</th>
<th>At Time of Slurry Introduction</th>
<th>At Time of Concreting (In Hole)</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (kN/m³)</td>
<td>10-10.1</td>
<td>10-10.17</td>
<td>Density Balance</td>
</tr>
<tr>
<td>Viscosity (sec/liter)</td>
<td>32-42</td>
<td>32-42</td>
<td>Marsh cone</td>
</tr>
<tr>
<td>pH</td>
<td>9-11</td>
<td>9-11</td>
<td>pH paper or meter</td>
</tr>
</tbody>
</table>

Note: Density values shown are for fresh water. For salt water density values shall be increased by 0.32 kN/m³. Perform tests when slurry temperature is above 4°C. If desanding is required, sand content shall not exceed four percent (4%) by volume at any point in the bore hole according to the American Petroleum Institute sand content test.

Tests to determine density, viscosity, and pH values shall be performed before or during the shaft excavation to establish a consistent working pattern.

Prior to placing shaft concrete, the Contractor shall use an approved slurry sampling tool to take slurry samples from the bottom and at mid height of the shaft. Any heavily contaminated slurry that has accumulated at the bottom of the shaft shall be eliminated.
The mineral slurry shall maintain the proper physical properties as per the specification requirements before the placement of the concrete in the shaft.

7.4. Driven Piles Construction

7.4.1. Preparation for Driving

7.4.1.1. Site Work

1. Excavation
   If practical, piles shall not be driven until after the excavation is complete. Any material forced up between the piles shall be removed to the correct elevation before concrete for the foundation is placed.
   Unless otherwise approved by the Engineer, piles at bridge ends shall not be driven until roadway embankments are placed.

2. Pre-drilling to Facilitate Driving
   When required by the contract documents, the Contractor shall pre-drill holes of a size specified, at pile locations, and to the depths shown in the contract documents or approved in writing by the Engineer. Any void space remaining around the pile after completion of driving shall be filled with sand or other approved material. The use of spuds shall not be permitted in lieu of pre-drilling, unless specified in the contract documents or approved in writing by the Engineer. Material resulting from drilling holes shall be disposed of as approved by the Engineer.

3. Additional Requirements for Predrilled Holes in Embankments
   If required by the contract documents, piles to be driven through compacted fill or embankment of a depth greater than 1.5 m shall be driven in holes predrilled to natural ground. After driving the pile; the space around the pile shall be filled to the ground surface with sand or other approved material. Material resulting from pre-drilling holes shall be disposed of as approved by the Engineer.

7.4.1.2. Preparation of Piling

1. Pile Heads
   For steel piling, the pile heads shall be cut and maintained square with the longitudinal axis of the pile. Precast concrete pile heads shall be flat, smooth, and perpendicular to the longitudinal axis of the pile to prevent eccentric impacts from the helmet. Prestressing strands shall be cut off below the surface of the end of the pile. For concrete or timber piles, the pile head shall be chamfered on all sides.

2. Collars (metal hoops)
   When wooden piling is required with largest nominal resistance of 981 kN or when drilling conditions require it, collars or any other tools like metal collars should be used to protect the piles of divisions and the fragmentation or separation of the wood fibers at the end of Piles.
3. **Pile Shoes and End Plates**

Pile shoes shall be used when specified by the Engineer or in the contract documents to protect all types of piles when hard driving or obstructions are expected.

Steel pile shoes shall be fabricated from cast steel conforming to ASTM A 148/A 148M (Grade 90-60).

End plates used on closed-end pipe piles shall be made of ASTM A 36/A 36M steel or better. The diameter and thickness shall be specified by the Engineer.

7.4.2. **Pile Driving Equipment**

All pile driving equipment, including the pile driving hammer, hammer cushion, helmet, pile cushion, and other appurtenances to be furnished by the Contractor shall be approved in advance by the Engineer before any driving can take place. Pursuant to obtaining this approval, the Contractor shall submit a description of pile driving equipment to the Engineer at least two weeks before the onset of pile driving. The description shall contain sufficient detail so that the proposed driving system can be evaluated by wave equation analysis.

If the nominal resistance is to be determined by static load test, dynamic test, quick static load test, or wave equation analysis, the Contractor shall submit to the Engineer results of a wave equation analysis to show that the piles are drivable.

If the nominal resistance is to be determined by dynamic formula, a wave equation analysis is not required. The blow count required by the dynamic formula shall not exceed 10 blows per 25 mm.

The following hammer efficiencies shall be used in a wave equation analysis of vertical piles unless better information is available (AASHTO 2008) as presented in Table 7.3.

<table>
<thead>
<tr>
<th>Hammer Type</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-acting air/steam</td>
<td>67</td>
</tr>
<tr>
<td>Double-acting air/steam</td>
<td>50</td>
</tr>
<tr>
<td>Diesel</td>
<td>80</td>
</tr>
<tr>
<td>Hydraulic or diesel with built-in energy</td>
<td>95</td>
</tr>
</tbody>
</table>

Hammer efficiencies shall be adjusted for better driving the piles.

In addition to the other requirements of these Specifications, the criterion that the Contractor and the Engineer will use to evaluate the driving equipment shall consist of both the required number of hammer blows per 25 mm at the required nominal resistance and the pile driving stresses over the entire driving process. The required number of hammer blows indicated by the wave equation analysis at the required nominal resistance shall be between 2 and 10 blows per 25 mm. for the driving equipment to be deemed acceptable.

In addition, for the driving equipment to be deemed acceptable, the pile stresses, which are determined by the wave equation analysis for the entire driving operation, shall not exceed the values below:
Section 7: Piling and Drilled Shafts Construction

Driven Piles Construction

Tensile stresses \( \leq 0.63 \sqrt{f'_c} + EPV \)

Compressive stresses \( \leq 0.85 f'_c - EPV \)

*Where:*

\( f'_c = \) Concrete compressive strength (MPa).

\( EPV = \) Effective Prestress Value.

Effective Prestress value = Prestress value after all losses (MPa).

During pile driving operations, the Contractor shall use the approved system. Any change in the driving system shall be considered only after the Contractor has submitted revised pile driving equipment data and wave equation analysis. The Contractor shall be notified of the acceptance or rejection of the driving system changes within two working days of the receipt of the requested changes by the Engineer. The time required for submission, review, and approval of a revised driving system shall not constitute the basis for a contract time extension to the Contractor.

Approval of pile driving equipment shall not relieve the Contractor of responsibility to drive piles, free of damage, to the required nominal resistance and, if specified, the minimum penetration, shown in the contract documents.

7.4.2.1. Hammers

1. General

Piles shall be driven with an impact or vibratory hammer conforming to these Specifications. Pile driving hammers shall be of the size needed to develop the energy required to drive the piles at a blow count that does not exceed 10 blows per 25 mm at the required nominal resistance.

2. Drop Hammers

Drop hammers shall not be used for concrete piles or for piles whose required nominal resistance exceeds 588 kN.

Where drop hammers are permitted, the ram shall have a weight not less than 10 kN and the height of drop shall not exceed 3.7 m. In no case shall the ram weight of drop hammers be less than the combined weight of helmet and pile. All drop hammers shall be equipped with hammer guides and a helmet to ensure concentric impact.

3. Air Hammers

If a dynamic formula is used to establish the required blow count, the weight of the striking parts of air hammers used shall not be less than one-third the weight of pile and drive cap, and in no case shall the striking part have a weight less than 14 kN. If a wave equation analysis is used to establish the required blow count and driving stresses, this limitation on ram weight shall not apply.

The plant and equipment furnished for air-hammers shall have sufficient capacity to maintain, under working conditions, the pressure at the hammer specified by the Manufacturer. The hose connecting the compressor with the hammer shall be at least the minimum size recommended by the Manufacturer.

Hammer performance shall be evaluated at the end of driving by measuring blows per minute and comparing these blows with the Manufacturer's recommendations.
4. Diesel Hammers

If open-end (single-acting) diesel hammers are not equipped with a device to measure impact velocity at all times during pile driving operations, the stroke shall be obtained by measuring the speed of operation either manually or with a device that makes the measurement automatically.

Closed-end (double-acting) diesel hammers shall be equipped with a bounce chamber pressure gauge in good working order, mounted near ground level so as to be easily read by the Engineer. The Contractor shall provide a correlation chart of bounce chamber pressure and potential energy.

5. Hydraulic Hammers

Hydraulic hammers shall be equipped with a system for measuring ram energy. The system shall be in good working order and the results shall be easily and immediately available to the Engineer.

6. Vibratory Hammers

Vibratory or other pile driving methods may be used only when specified in the contract documents or specified in writing by the Engineer. Except when pile lengths have been evaluated from static load test of piles, the nominal resistance of piles driven with vibratory hammers shall be verified by additional driving of the first pile driven in each group of 10 piles with an impact hammer of suitable energy to measure the nominal resistance before driving the remaining piles in the group. In case of variable soils, additional piles shall be verified by an impact hammer as directed by the Engineer. All piles that rely primarily on point bearing capacity shall be re-driven with an impact hammer.

Vibratory hammers shall not be used to drive concrete piles.

7. Additional Equipment or Methods

In case the required penetration is not obtained by the use of a hammer complying with the minimum requirements above, the Contractor may be required to provide a hammer of greater energy or, when permitted, resort to supplemental methods such as jetting or pre-drilling.

7.4.2.2. Driving Appurtenances

1. Hammer Cushion

All impact pile driving equipment except drop hammers shall be equipped with a suitable thickness of hammer cushion material to prevent damage to the hammer or pile. Hammers designed such that a hammer cushion is not required shall be excluded from this requirement.

Where applicable, hammer cushions shall be made of durable, manufactured materials that will retain uniform properties during driving. Wood, wire rope, or asbestos hammer cushions shall not be used. A striker plate shall be placed on the hammer cushion to ensure uniform compression of the cushion material. The hammer cushion shall be replaced by the Contractor before driving is permitted to continue whenever there is a reduction of hammer cushion thickness exceeding twenty-five percent (25%) of the original thickness or, for air hammers, when the reduction in thickness exceeds the Manufacturer's recommendations.
2. Helmet

Piles driven with impact hammers shall be fitted with a helmet to distribute the hammer blow uniformly and concentrically to the pile head. The surface of the helmet in contact with the pile shall be plane and smooth and shall be aligned parallel with the hammer base and the pile top. It shall be guided by the leads and not be free-swinging. The helmet shall fit the pile head in such a manner as to maintain concentric alignment of hammer and pile.

For special types of piles, appropriate driving heads, mandrels, or other devices shall be provided so that the piles may be driven without damage.

For timber piles, the least inside helmet or hammer base horizontal dimension shall not exceed the pile head diameter by more than 51 mm. If the timber pile diameter slightly exceeds the least helmet or hammer base dimension, the pile head shall be trimmed to fit the helmet.

3. Pile Cushion

A pile cushion shall protect the heads of concrete piles. The cushion thickness placed on the pile head before driving shall be selected by wave equation analysis so that the limiting driving stresses are not exceeded. If the required driving blow count is determined by a dynamic formula, the cushion shall have a thickness of at least 102 mm.

A new pile cushion shall be provided if, during driving, the cushion begins to smoke or excessive compression occurs. The pile cushion dimensions shall be such as to distribute the blow of the hammer uniformly over the entire cross-section of the pile.

Pile cushions shall be protected from the weather and kept dry before use. Pile cushion shall not be soaked in any liquid unless approved by the Engineer. The use of manufactured pile cushion materials in lieu of a wood pile cushion shall be evaluated on a case-by-case basis.

A used pile cushion in good condition shall be used for restrike tests.

4. Leads

Pile driving leads that align the pile and the hammer in proper positions throughout the driving operation shall be used. Leads shall be constructed in a manner that affords freedom of movement of the hammer while maintaining alignment of the hammer and the pile to ensure concentric impact for each blow.

The leads shall be designed to permit proper alignment of battered piles when applicable.

Leads may be either fixed or swinging type.

Swinging leads, when used, shall be fitted with a pile gate at the bottom of the leads. The leads shall be adequately embedded in the ground or the pile constrained in a structural frame such as a template to maintain alignment.

5. Followers

Followers shall be used only when approved in writing by the Engineer or when specified in the contract documents.

For concrete piles, a pile cushion shall be used at the pile top, and suitability of the follower shall be checked by wave equation analysis to verify the blow count, driving stresses, and nominal resistance.
For steel or timber piles, if a wave equation analysis is not performed, the follower shall have an impedance between fifty percent (50\%) and two hundred percent (200\%) of the pile impedance.

The follower and pile shall be maintained in proper alignment during driving. The follower shall be of such material and dimensions to permit the piles to be driven to the blow count determined to be necessary.

6. Jetting

Jetting shall be permitted only if specified in the contract documents or approved in writing by the Engineer.

The Contractor shall determine the number of jets and the volume and pressure of water at the jet nozzles necessary to freely erode the material adjacent to the pile.

The Contractor shall control and dispose of all jet water in a manner satisfactory to the Engineer, or as specified in the contract documents. If jetting is specified or approved by the Engineer and is performed according to the specifications or as approved by the Engineer, the Contractor shall not be held responsible for any damage to the site caused by jetting operations. If jetting is used for the Contractor's convenience, the Contractor shall be responsible for all damages to the site caused by jetting operations.

Unless otherwise indicated by the Engineer or the contract documents, jet pipes shall be removed before or when the pile tip is 1.5 m above the minimum or final tip elevation, and the pile shall then be driven without jetting to the final tip elevation or to the required nominal resistance with an impact hammer. If the required nominal resistance is not reached at the final tip elevation, the pile may be allowed to set up and then the required nominal resistance will be determined by re-striking the pile.

7.4.3. Driving

Unless approved by the Engineer, piles shall be driven to:
- The required nominal resistance, or
- The required nominal resistance and minimum tip elevation, if specified, or
- The specified tip elevation.

The blow count shall always be measured, either during initial driving or by re-driving with a warm hammer after a wait period, as determined by the Engineer.

For diesel hammers, the stroke shall be recorded. For hydraulic hammers, either energy or impact velocity shall be recorded.

If water jets are used in connection with the driving, the nominal resistance shall be determined from the results of driving after the jets have been withdrawn.

The procedure used in driving the piles shall not subject them to excessive and undue abuse producing crushing and spalling of the concrete, injurious splitting, splintering and brooming of the wood, or excessive deformation of the steel.

7.4.3.1. Heaved Piles

If pile heave is observed, level readings referenced to a fixed datum shall be taken by the Engineer on all piles immediately after installation and periodically thereafter as adjacent piles are driven to determine the pile heave range.

During the driving process for adjacent piles, piles shall be re-driven:
- If they heave more than 12.7 mm and end bearing is dominant, or
- If they heave more than 38 mm and shaft friction is dominant.

If pile heave is detected for pipe or shell piles that have been filled with concrete, the piles shall be re-driven to original position after the concrete has obtained sufficient strength, and a proper hammer-pile cushion system, satisfactory to the Engineer, is used. The Contractor shall be paid for all work performed in conjunction with re-driving piles because of pile heave provided the initial driving was done in accordance with the specified installation sequence.

7.4.3.2. Obstructions

If piles encounter unforeseeable, isolated obstructions, the Contractor shall be paid for the cost of obstruction removal and for all remedial design or construction measures caused by the obstruction.

7.4.3.3. Installation Sequence

The order of installing piles in pile groups shall be either starting from the center of the group and proceeding outward in both directions or starting at the outside row and proceeding progressively across the group.

7.4.3.4. Limiting Driving Stresses

Unless specified otherwise in the contract documents or by the Engineer, the stresses induced during driving shall not exceed the limits set forth in Article 7.4.1, "Preparation for Driving".

7.4.3.5. Driving of Probe Piles

Where required in the contract documents, probe piles shall be furnished to the lengths specified and driven at the locations and to the elevations, nominal resistances, or blow counts directed by the Engineer before other piles are ordered. All piles shall be driven with approved impact hammers unless specifically stated otherwise in the contract documents. The same type and size hammer shall be used on the production piles.

The approval of driving equipment shall conform to the requirements of these Specifications. Unless otherwise approved by the Engineer, the Contractor shall excavate the ground at each probe pile to the elevation of the bottom of the footing before the pile is driven (see Article 7.4.1.1.1, "Excavation"). Additional probe piles shall be driven at locations selected by the Engineer to explore possible subsurface variations.

When ordered by the Engineer, probe piles driven to plan grade and not having the required nominal resistance shall be spliced and driven until the required bearing is obtained.

7.4.3.6. Accuracy of Driving

Piles shall be driven with a variation of not more than (1:50) from the vertical or not more than (1:25) from the batter shown in the contract documents, except that piles for trestle bents shall be driven so that the cap may be placed in its proper location without adversely affecting the resistance of the piles.
After driving, the pile head shall be within 150 mm of plan locations for all piles
capped below final grade, and shall be within 75 mm of plan locations for bent caps
supported by piles

No pile shall be nearer than 100 mm from any edge of the cap. Any increase in pile
cap dimensions or reinforcing caused by out-of-position piles shall be at the
Contractor's expense.

7.4.4. Determination of Nominal Resistance

7.4.4.1. General

The nominal resistance of piles will be determined by the Engineer using the
method specified in the contract documents. The method used to determine resistance
of piles during or after installation shall be consistent with the pile resistance
verification methodology assumed during the project design phase in accordance with
Article 8.5.5.2.3 of the (MA-100-D-V2/2).

7.4.4.2. Static Load Tests

If a static load test is used to determine the pile axial resistance, the test shall not be
performed less than five days after the test pile was driven unless approved by the
Engineer or otherwise specified in the contract documents. The static load test shall
follow the procedures specified in ASTM D 1143/D 1143M, and the loading procedure
should follow the Quick Load Test Method, unless detailed longer-term load-settlement
data are needed, in which case the standard loading procedure should be used. Testing
equipment and measuring systems shall conform to ASTM D 1143/D 1143M. The
equipment to conduct the static load test shall be supplied by the entity specified in the
contract documents. The Engineer or a disinterested testing laboratory shall perform the
test.

The Contractor shall submit detailed contract documents of the proposed loading
apparatus, prepared by a professional engineer, to the Engineer for approval. The
submitter shall include calibrations for the hydraulic jack, load cell, and pressure gauge
conducted within 30 days before mobilization to the job site. When the approved
method requires the use of tension (anchor) piles that will later be used as permanent
piles in the work, such tension piles shall be of the same type and size as the production
piles and shall be driven in the location of permanent piles where feasible.

While performing the static load test, the Contractor shall provide safety equipment
and employ adequate safety procedures. Adequate support for the static load test plates,
jack, and ancillary devices shall be provided to prevent them from falling in the event
of a release of load due to hydraulic failure, test pile failure, or other causes.

The method of defining failure of the static load test shall be as defined in the
contract documents or by the Engineer. Based on the static load test results, the
Engineer shall provide the driving criteria for production pile acceptance.

When specified, tension static load tests shall be conducted in accordance with
ASTM D 3689 Specifications. When specified, lateral load tests shall be conducted in
accordance with ASTM D 3966 Specifications.
7.4.4.3. Dynamic Testing

Dynamic testing shall be conducted in accordance with ASTM D 4945 Specifications. The Contractor shall prepare for the required instrumentations or attachments as directed by the Engineer.

The Contractor shall drive the pile as directed by the Engineer, whereby, if directed by the Engineer, the Contractor shall reduce the driving energy transmitted to the pile by using additional cushion or reducing the energy output of the hammer to maintain acceptable stresses in the piles. If non-axial driving is indicated by dynamic measurements, the Contractor shall immediately realign the driving system.

If the required nominal resistance is not achieved at the end of driving, the Contractor shall re-strike the dynamic test pile following a waiting period specified in the contract documents or as directed by the Engineer. Once the waiting period is completed, the dynamic testing instruments shall be reattached, the pile shall be re-driven, and the dynamic test shall be repeated. The hammer shall be warmed up before re-striking begins. The maximum penetration required during re-striking shall be 75 mm, or a maximum of 20 blows shall be obtained, whichever occurs first.

7.4.4.4. Wave Equation Analysis

When specified in the contract documents, the Engineer using a wave equation analysis shall determine the driving criterion necessary to reach the required nominal resistance of the pile. Soil and pile properties to be used in this analysis shall be as shown in the contract documents or as determined by the Engineer. The Contractor shall supply the Engineer with the necessary information on the proposed driving equipment to perform the wave equation analysis.

7.4.4.5. Dynamic Formula

When using a dynamic formula, the particular formula shall be specified in the contract documents. A dynamic formula should not be used if the required nominal resistance is more than 4137 MPa.

Formulas shall be considered applicable only where:
- the head of the pile is not broomed, crushed, or otherwise damaged, and
- a follower is not used.

If a dynamic formula is used to establish the driving criterion, the Federal Highway Administration (FHWA) Gates Formula specified herein should be used. The nominal pile resistance as measured during driving using this method shall be taken as follows:

$$ R_{ndr} = 10.4 \sqrt{E_d} \log_{10} (10N_b) - 689.5 $$

Where:

- $R_{ndr}$ = Nominal pile resistance measured during pile driving (MPa)
- $E_d$ = Developed hammer energy. This is the kinetic energy in the ram at impact for a given blow. If ram velocity is not measured, it may be assumed equal to the potential energy of the ram at the height of the stroke, taken as the ram weight times the stroke (N.mm)
- $N_b$ = Number of hammer blows for 25 mm of pile permanent set (blows/25 mm.)

If a dynamic formula other than those provided herein is used, it shall be calibrated based on measured static load test results to obtain an appropriate resistance factor, consistent with Article C 8.5.5.2 of the (MA-100-D-V2/2).
7.4.5. Splicing of Piles
Where splices are unavoidable for steel or concrete piles, their number, locations, and details shall be subject to approval of the Engineer. The splice detail shall be adequate to sustain the driving stresses and perform adequately under the structural loads imparted on the pile for various limit states and load combinations.

7.4.5.1. Concrete Piles
Full-length piles shall be used where practical. Where splicing is permitted, concrete pile splice details shall conform to the contract documents, or as approved by the Engineer. Mechanical splices including drive-fit splices may also be used.

7.4.6. Defective Piles
Manipulation of piles to force them into proper position, considered by the Engineer to be excessive, shall not be permitted. Improper manipulations may cause residual damages that adversely affect the pile performance under various loadings carried by the pile.

Any pile damaged by reason of internal defects or by improper driving shall be corrected at the Contractor's expense by one of the following methods approved by the Engineer for the pile in question:
- The pile is withdrawn if practicable, and replaced by a new and, if necessary, longer pile.
- One or more replacement piles are driven adjacent to the defective pile.

A pile driven below the specified butt elevation shall be corrected by one of the following methods approved by the Engineer for the pile in question:
- The pile is spliced or built up as provided herein.
- A sufficient portion of the footing is extended down to properly embed the pile.

A pile driven out of its proper location, specified in the contract documents or by the Engineer, shall be corrected by one of the following methods approved by the Engineer for the pile in question:
- One or more replacement piles are driven next to the out-of-position piles.
- The footing is extended laterally to incorporate the out-of-location pile.
- Additional reinforcement is added.

All such remedial materials and work shall be furnished at the Contractor's expense.

7.4.7. Pile Cut-Off
All piles shall be cut off to a true plane at the elevations required and anchored to the structure as shown in the contract documents. All cut-off lengths of piling shall remain the property of the Contractor and shall be properly disposed of.

7.5. Drilled Shafts Construction

7.5.1. Protection of Existing Structures
All precautions shall be taken to prevent the damage to existing structures and utilities. These measures shall include but are not limited to, selecting construction methods and procedures that will prevent excessive caving of the shaft excavation,
monitoring, and controlling the vibrations from driving of casing or sheeting, drilling of the shaft or from blasting, if permitted.

7.5.2. Construction Sequence

All excavations of the foundation in which drilled shafts are to be constructed shall be complete before shaft construction begins.

Unless shown otherwise in the contract documents where drilled shafts are to be installed in conjunction with embankment placement, they shall be constructed after the placement of the fill.

7.5.3. Construction Methods

Excavations required for shafts and bell footing shall be performed through whatever materials are encountered, to the dimensions and elevations in the contract documents or ordered by the Engineer. The methods and equipment used shall be suitable for the intended purpose and materials encountered. Generally, either the dry method, wet method, temporary casing method, or permanent casing method may be used as necessary to produce sound, durable concrete foundation shaft free of defect.

The permanent casing method shall be used only when required by the contract documents or authorized by the Engineer. When a particular method of construction is required in the contract documents, that method shall be used. If no particular method is specified for use, the Contractor shall select and use the method that is needed to properly accomplish the work, as determined by site conditions and subject to approval of the Engineer.

7.5.3.1. Trial Drilled Shafts

1. General

The Engineer will require the construction of a trial shaft if the submittal of descriptions of previous drilled shaft construction projects does not, in the opinion of the Engineer, substantiate the Contractor's capability for constructing the drilled shafts on this project. The Engineer may also require the construction of a trial shaft to verify the adequacy of unusual construction methods and/or equipment proposed for use in the construction of the production shafts.

The trial drilled shaft shall be constructed if required by special note on the plans.

2. Location and Depth

The trial shaft(s) shall be positioned as indicated on the plans or as directed by the Engineer. Unless otherwise indicated, shafts shall be drilled to the maximum depth of any production shaft shown on the plans.

3. Failure to Demonstrate Ability

Failure of the Contractor to demonstrate the adequacy of his equipment, methods and/or expertise shall be reason for the Engineer to require alterations necessary to eliminate unsatisfactory results. Additional trial shafts required to demonstrate correction of deficiencies shall be at the Contractor's expense.
4. Trial Shaft Approval

Once approval has been given to construct production shafts, no changes will be permitted in the personnel, methods or equipment that were used to construct the satisfactory trial shaft without written approval of the Engineer.

5. Site Restoration

Unless otherwise shown in the contract documents, the trial shaft holes will be filled with non-reinforced concrete in the same manner that production shafts will be constructed. The concrete filled trial shafts shall be cutoff 600 mm below finished grade or at the mudline if in water. The disturbed areas at trial shaft holes shall be restored as nearly as practical to their original condition. No direct payment will be made for cutting off the top of the trial shaft or for the site restoration.

7.5.3.2. Drilled Shafts

1. Hole Excavation

a. General

The bottom elevation of the drilled shaft shown on the plans may be adjusted during construction if the Engineer determines that the foundation material encountered during excavation is unsuitable or differs from that anticipated in the design of the drilled shaft:

When specified or shown in the plans, the Contractor shall take soil samples or rock cores to determine the character of the material directly below the shaft excavation. The Engineer will inspect the samples or cores and determine the final depth of required shaft excavation.

Excavated materials which are removed from the shaft excavation and any drill fluids used shall be disposed of in accordance with the special provisions, and in compliance with local regulations.

When bell footings are shown in the plans they shall be excavated to form a bearing area of the size and shape shown.

Excavation Inspection: The Contractor shall provide equipment for checking the dimensions and alignment of each shaft excavation. The dimensions and alignment shall be determined by the Contractor under the direction of the Engineer. Final shaft depth shall be measured after final cleaning. The excavated shaft shall have the approval of the Engineer prior to proceeding with construction.

b. Dry Method

When the site conditions are in a relatively dry land where the groundwater table is very deep and site conditions are suitable to permit construction of the shaft, Dry construction method is used.

The sides and bottom of the shaft remain stable without any caving, sloughing or swelling and may be visually inspected prior to placing the concrete.

The dry method consists of drilling the shaft excavation, removing accumulated water and loose material from the excavation, placing the reinforcing cage, and placing the shaft concrete in a relatively dry excavation.
c. Wet Method

When the located sites are in area where a dry excavation cannot be maintained for placement of the shaft concrete, the wet construction method is employed. This method consists of using water or mineral slurry to maintain stability of hole's perimeter while advancing the excavation to final depth, placing the reinforcing cage, and concreting the shaft.

The wet and dry methods involve the work indicated in Table 7.

<table>
<thead>
<tr>
<th>Works involved</th>
<th>Wet Method</th>
<th>Dry Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desanding and cleaning the slurry.</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Final cleaning of the excavation using a bailing bucket, air lift, submersible pump, or other approved devices.</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Placing the shaft concrete with a tremie or concrete pump beginning at the shaft bottom.</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Providing, as needed, temporary surface casings to aid shaft alignment and positioning.</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Providing temporary surface casings to prevent sloughing of the top of the shaft excavation unless it can be satisfactorily demonstrated that the surface casing is not required.</td>
<td>YES</td>
<td>NO</td>
</tr>
</tbody>
</table>

d. Casing Methods

d1. Temporary Casing Construction Method

Whenever the stability of the excavated hole and/or the effects of groundwater cannot be controlled by other means, temporary casing construction method is adopted. It can be used at all sites.

Temporary casing may be installed by driving or vibratory procedures in advance of excavation to the lower limits of the caving material.

Removable of Temporary casing is permissible when the concrete remain workable with slump value not less than 100 mm. A minimum of 1.5 m head of fresh concrete is to be maintained before the casing removal so that all the fluid trapped behind the casing is displaced upward without contaminating the shaft concrete. The provided minimum concrete head may have to be increased to counteract groundwater head outside the casing. Casing shall be removed by a rotary movement, downward pressure and tapping to ease the extraction or extraction, with a vibratory hammer can be employed. Casing extraction shall be at a slow and uniform rate with the pull in line with the shaft axis.

d2. Permanent Casing Construction Method

In this method, driving or drilling a casing to a prescribed depth before excavation begins. If full penetration cannot be attained, the Contractor may either excavate
material within the embedded portion of the casing or excavate a pilot hole ahead of the casing until the casing reaches the desired penetration. The pilot hole shall be no larger than one-half the diameter of the shaft and shall be centered in the shaft. Over reaming to the outside diameter of the casing shall not be performed until and unless stated in the Plans or Special Provisions.

Continuous casing shall be done between the elevations. Avoid use of temporary casing in lieu of or in addition to the permanent casing unless mentioned on plans.

After the installation of the casing and the excavation of the shaft is complete, the reinforcing steel shall be placed, followed by the placement of the shaft concrete. After the permanent casing has been filled with concrete, pressure grouting with cement grout shall be done so as to fill any voids between the shaft excavation and the casing. The method of pressure grouting the voids shall be submitted to the Engineer for approval.

*Note:* Pressure grouting is required to assure contact (bearing) between the casing and any surrounding soil layer that is utilized for lateral support.

d3. Double Casing Method

As an alternative to the temporary casing method when groundwater or unstable soil conditions are severe the double casing construction method is employed unless specified in the documents. This method is similar to the temporary casing method except that the temporary exterior casing is larger than the specified shaft diameter and a permanent interior casing (corrugated galvanized steel pipe) is set into the top of the founding stratum after the excavation is complete.

The interior casing shall be supplied with a permanent inner diameter equal to the plan shaft diameter, and use a temporary exterior casing having an inner diameter at least 150 mm greater than the interior casing. After the exterior casing is in place, the excavation is completed as per the plan shaft diameter and the interior casing is set into the top of the founding stratum, bracing the interior casing at the top. The temporary casing is to be filled with concrete, only after filling interior casing with concrete, adding concrete as needed to maintain top of shaft elevation during removal. If the concrete has taken initial set, the position of interior casing shall not be disturbed.

d4. Obstructions

When the excavation cannot be advanced through unexpected manmade materials, the removal of the manmade materials is considered an obstruction. Removal of naturally-occurring material, regardless of difficulty or removal method, is not considered an obstruction. Removal of tools lost in the excavation by the Contractor is not considered an obstruction.

When encountered, the Contractor shall remove the obstructions and notify the Engineer, in advance, of the proposed method for obstruction removal. If additional compensation for obstruction removal is sought, the estimated cost for excess costs under site conditions must be included. Blasting methods shall not be used unless permitted by the Engineer.

Drilling tools which are lost in the excavation shall not be considered obstructions and shall be promptly removed by the Contractor without compensation. All costs due to lost tool removal shall be the responsibility of the Contractor, including costs associated with correcting hole degradation due to removal operations and any time delays.
2. Excavation Inspection

a. Inspection Equipment

The contractor shall maintain at the job at all times, all equipment suitable for use in the shaft inspection.

b. Removal of Excess Sediment and Water

Final shaft depth shall be measured with approved methods after final cleaning by airlift, or other method approved by the engineer. Unless otherwise stated in the contract documents, a minimum of fifty percent (50%) of the base of each shaft shall have less than 13 mm of sediment at the time of concrete placement. The maximum depth of sediment or any debris at any place on the base of the shaft shall not exceed 38 mm. For dry excavations, the maximum depth of water shall not exceed 75 mm prior to concrete pour. Shaft cleanliness will be verified by the engineer for wet or dry shafts.

c. Television Camera Inspection

The primary means of inspecting a shaft excavation, steel casing and the rock socket shall be by television camera lowered into the shaft. The contractor shall furnish all equipment necessary to conduct the camera inspection. The contractor shall operate the camera and supporting equipment under the direction of the engineer in such a manner as to obtain optimum results from the equipment. The television camera and lighting equipment shall be capable of operating in dry or submerged conditions encountered during the inspection. The excavated shaft shall have the engineer’s approval prior to proceeding with construction.

c1. Equipment

Methods and equipment for controlling the camera will be subject to approval from the engineer and achievement of a satisfactory video record.

c2. Drawings

The contractor shall submit layout drawings to the engineer showing the relative position of all components of the television inspection system, including type and size of barge or other work area. The information submitted shall include a written description of the operating procedure in a step-by-step sequence and shall state the source of power.

c3. Shaft Inspection

Inspection of a shaft by television camera shall be performed as directed by the engineer. The excavated shaft, including the rock socket when applicable, shall be thoroughly cleaned of all loose fragments, sediment and turbidity prior to inspection. The camera shall be operated such that optimum clarity of detail can be obtained and all surface areas of the shaft, including the rock socket and the rock socket’s base, can be observed. All scanning of the rock surfaces shall be recorded on videotape. After completion of the inspection of a rock socket, the engineer will direct whether or not drilling of the shaft shall be continued to a greater depth. All tapes shall be stored in proper containers with dust-tight closures and shall be properly labeled as to shaft number along with project and contractor identification. Tapes shall be furnished to and shall become the property of the engineer upon completion of the work.
3. Exterior Casing

Installation shall be done for all casings to produce a positive seal that prevents piping of water or other material into or out of the hole. If it becomes necessary to remove a casing and substitute a longer or larger diameter casing through caving soils, stabilize the excavation with slurry or backfill before the new casing is installed. Other approved methods may be used to control the stability of the excavation and protect the integrity of the foundation soils.

All subsurface exterior casings are to be considered temporary unless designated in the contract as permanent casing. Remove temporary casing before completing the placement of concrete in any cased drilled shaft. During casing removal from the hole, maintain a level of fresh concrete in the casing that is a minimum of 1.5 m above the surrounding level of water or slurry. Extensive care shall be taken during casing removal to maintain an adequate level of concrete within the casing so that the fluid trapped behind the casing is displaced upward and discharged at the ground surface without contaminating or displacing the shaft concrete.

Temporary casings that have become bound or fouled during shaft construction and cannot be practically removed are considered a defect in the drilled shaft.

Casings shall be extended above the ground surface to keep the excavation clean through concrete placement. When a casing is designated as permanent, the casing shall be cut off at the required elevation and left in place after concrete placement.

4. Reinforcing Steel Cage Construction and Placement

a. General

After the shaft excavation is inspected and accepted, immediately place the reinforcing steel cage as a unit and concrete placement shall be done soon after that. Securely wire together contact reinforcing steel lap splices. If the concrete is not placed immediately after the cage is installed, the cage may have to be removed before placing the concrete to verify the integrity of the excavated area and to ensure loose material is removed from the bottom of the hole.

The reinforcing steel shall be tied and supported so that it remains within the required tolerances. Securely tie concrete spacers or other approved spacing devices at fifth points around the cage perimeter and space at intervals not to exceed 3 meters along the length of the cage. Use spacers of approved material equal in quality and durability to the shaft concrete.

During concrete placement, provide positive support from the top for the reinforcing steel cage. Support the cage concentrically to prevent racking and distortion of the cage. Maintain the top of the reinforcing steel cage no more than 150 mm above and no more than 75 mm below the required position. If the reinforcing steel cage is not maintained within tolerances, make acceptable corrections and do not construct additional shafts until the method of reinforcing steel cage support has been approved.

If it is determined in the field that the shaft must be longer than planned, provide reinforcing steel for the extended length, and ensure proper splice length and procedures as directed by these specifications or approval of the Engineer.

The reinforcing steel cage consisting of the steel shown on the plans plus cage stiffener bars, spacers, centralizers, and other necessary appurtenance shall be completely assembled and placed as a unit immediately after the shaft excavation is inspected and accepted and prior to shaft concrete placement. The reinforcing cage
shall be rigidly braced to retain its configuration during handling and construction. Individual or loose bars shall not be used. The Contractor shall show bracing and any extra reinforcing steel required for fabrication of the cage on the shop drawings.

The reinforcement shall be carefully positioned and securely fastened to provide the minimum clearances listed below, and to ensure that no displacement of the reinforcing steel bars occurs during placement of the concrete.

Bars shall be placed as shown in the contract plans with concrete cover as shown in Table 7.5.

<table>
<thead>
<tr>
<th>Shaft Diameter</th>
<th>Uncased</th>
<th>Casing Remains</th>
<th>Casing Withdrawn</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 m or less</td>
<td>80 mm</td>
<td>80 mm</td>
<td>110 mm</td>
</tr>
<tr>
<td>0.61 m</td>
<td>80 mm</td>
<td>80 mm</td>
<td>110 mm</td>
</tr>
<tr>
<td>1.22 m</td>
<td>110 mm</td>
<td>110 mm</td>
<td>110 mm</td>
</tr>
<tr>
<td>1.53 m or larger</td>
<td>160 mm</td>
<td>160 mm</td>
<td>160 mm</td>
</tr>
</tbody>
</table>

b. Access Tubes for Crosshole Sonic Logging (CSL)

When CSL access tubes are specified in the contract documents, i.e., shown in the bid schedule, provide CSL testing access tubes for all drilled shafts including trial shafts.

The use of access tubes shall be made of schedule 40 steel pipe and having an inside diameter of 50 mm. The tubes, including pipe joints, shall have a round, regular internal diameter free of defects or obstructions to permit the free, unobstructed passage of a 33 mm diameter source and receiver probes. The tubes and joints shall be watertight and free from corrosion with clean internal and external surfaces to ensure passage of the probes and a good bond between the concrete and the tubes.

The installation of each access tube shall be of the full depth of each shaft to permit access of CSL testing equipment. Using the planned shaft diameter, the number of access tubes in each drilled shaft shall be determined and installed as specified in Table 7.6, unless otherwise specified in the contract documents.

<table>
<thead>
<tr>
<th>Planned Shaft Diameter (m)</th>
<th>Minimum Number of Access Tubes</th>
</tr>
</thead>
<tbody>
<tr>
<td>D ≤ 0.9</td>
<td>3</td>
</tr>
<tr>
<td>0.9 &lt; D ≤ 1.2</td>
<td>4</td>
</tr>
<tr>
<td>1.2 &lt; D ≤ 1.5</td>
<td>5</td>
</tr>
<tr>
<td>1.5 &lt; D ≤ 1.8</td>
<td>6</td>
</tr>
<tr>
<td>1.8 &lt; D ≤ 2.4</td>
<td>7</td>
</tr>
<tr>
<td>2.4 &lt; D ≤ 3.0</td>
<td>8</td>
</tr>
<tr>
<td>3.0 &lt; D ≤ 3.7</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 7.6: Minimum Number of Access Tubes per Drilled Shaft
Each tube shall be fitted with a watertight shoe on the bottom and a removable cap on the top. Securely attach the tubes to the interior of the reinforcement cage in a regular, symmetric pattern such that each tube is equally spaced from the others around the perimeter of the cage. Tubes shall be installed as near as possible to parallel and vertical as possible. Tubes shall be started at the shaft bottom and end at least 0.9 m above the shaft top. If the shaft top is subsurface, the tubes shall be extended at least 0.9 m above the ground and/or water surface level.

Care shall be taken during reinforcement installation operations in the drilled shaft hole so as not to damage the tubes. Before placement of concrete, fill the access tubes with clean water and cap the tube tops to keep out debris. After concrete placement, extensive care shall be taken when removing caps to avoid applying excess torque, hammering, or other stresses that could break the bond between the access tubes and the concrete.

7.5.3.3. Concrete Placement, Curing and Protection

Concrete placement shall commence immediately after completion of excavation, inspection and setting of the reinforcing cage, and shall continue in one operation, to the top of the shaft, or to a construction joint identified on the plans. An unforeseen stoppage of work may require a horizontal construction joint during the shaft construction. For this reason, an emergency construction joint method shall be submitted to the Engineer for approval prior to starting shaft construction.

Before placement in a wet hole, water in the hole shall be allowed to seek its natural hydraulic head.

The contractor shall place the discharge end of either a tremie or concrete pump at the shaft base elevation. The contractor shall keep the discharge end immersed at least 1.5 m below the surface of the fluid concrete. A positive head of concrete in the tremie or pump shall be maintained during concrete placement. If anytime during the concrete placement, the discharge end is removed from the fluid concrete column and discharges concrete above the rising concrete surface into displaced water, the reinforcing cage and concrete shall be removed, and any necessary sidewall removal shall be completed as directed, and the shaft shall be reconstructed.

For shafts less than 2.4 m in diameter, the elapsed time from the beginning of concrete placement in the shaft to the completion of placement shall not exceed 2 hours unless a shaft concrete retarder is approved by the Engineer. For shafts 2.4 m and greater in diameter, the concrete placing rate shall be not less than 9 m of shaft height per each 2 hours period providing a 100 mm minimum slump is maintained throughout the concrete placement based on tests of a trial mix. The concrete mix shall be of such design that the concrete remains in workable plastic state throughout the 2 hours placement limit.

Concrete shall be placed in one continuous operation from bottom to top of the shaft using either a tremie or concrete pump. Placing of concrete shall be continued after the shaft excavation is full and until acceptance quality concrete is evident at the top of the shaft. Before initial concrete set, the top 3 m of the shaft concrete shall be consolidated using acceptable vibratory equipment. The top of the shaft shall be finished within 25 mm higher to 75 mm lower than the required elevation. For wet holes, the concrete shall not be consolidated until all water above the concrete surface has been removed.

When the top of the shaft is above ground, the contractor shall use a removable form or other approved means to form the shaft from the top to a minimum of 0.6 m below finished ground. When the top of the shaft is below ground, a temporary
oversize surface casing shall be used to control caving of soil, etcetera, into the freshly placed concrete.

The shaft concrete shall be vibrated or rodded to a depth of 1.5 m below the ground surface except where soft uncased soil or slurry remaining in the excavation will possibly mix with the concrete.

Concrete will be sampled for acceptance at the point of discharge into the tremie or concrete pump hopper.

After placement, the temporarily exposed surfaces of the shaft concrete shall be cured in accordance with the provisions in Article [10.13]. "Curing Concrete" in these specifications.

No construction operations that would cause soil movement adjacent to the shaft, other than mild vibration, shall be conducted for at least 48 hours after shaft concrete has been placed.

Portions of drilled shafts exposed to a body of water shall be protected from the action of water by leaving the forms in place for a minimum of seven days after concrete placement.

1. Tremies

For concrete placement watertight tremies shall be used in either wet or dry holes. A tremie consists of a tube of sufficient length, weight, and diameter to discharge concrete at the shaft base. The tremie shall be made so that the bottom can be sealed and charged with concrete in the dry, and then opened when in place at the bottom of the shaft. Tremies that contain aluminum parts that will contact the concrete shall not be used. Tremie shall be made capable of being rapidly lowered to retard or stop the flow of concrete.

Tremie shall be made inside diameter at least 250 mm and not more than 350 mm. Inside and outside surfaces of the tremie shall be clean and smooth. The wall shall be thick enough to prevent crimping or sharp bends. The top shall be fitted with a hopper. The discharge end of the tremie shall be constructed to permit a free radial flow of the concrete during placement.

2. Concrete Pumps

Pumped concrete placement shall be used in either wet or dry holes. Use 100 mm minimum diameter discharge tubes with watertight joints. Discharge tube shall be placed at the shaft base elevation.

For wet holes, pumps shall be used with a device at the end of the discharge tube to seal out water while the tube is first being filled with concrete. If a plug is used, it shall be removed from the hole or use a plug made from approved material that will prevent a defect in the shaft if not removed.

7.5.3.4. Concrete Sampling

Sampling of fresh concrete shall be in accordance with AASHTO T 141, except that for central or truck mixed concrete, the entire sample for slump and air tests and for molding compressive strength specimens may be taken at one time after approximately one cubic meter (m³) of concrete has been discharged, instead of at three or more regular intervals during the discharge of the entire batch. Acceptability of the concrete for slump and air content and, if applicable, for strength requirements, will be determined by tests on these samples.
7.5.3.5. Consistency

The slump of the concrete shall be within the limits for the respective classes of concrete. The concrete shall be uniform in consistency and shall contain the minimum quantity of water required to produce the designated slump. The slump of concrete mixes will be determined in accordance with the net quantity after proper allowance AASHTO T 119. The quantity of mixing water in the concrete shall be considered has been made for absorption by the aggregate. The slump and mixing water content of the concrete, when placed in the work, shall conform to Table 10.1, Section 10 of these specifications.

7.5.3.6. Defective Shafts

Correction factor shall be applied for defective shafts using approved methods. A plan for corrective work shall be submitted for the approval. Corrective action may consist of, but not limited to, the following:
- Removing the shaft concrete and extending the shaft deeper to compensate for loss of frictional capacity in the cased zone when temporary casing cannot be removed.
- Providing straddle shafts to compensate for capacity loss.
- Providing a replacement shaft.

7.5.4. Alternative Construction Methods

The Contractor may propose alternative methods to prevent caving and control groundwater. Such proposals, accompanied by supporting technical data, shall be submitted in accordance with Article 7.2.2 "Working Drawing", and are subject to the approval of the Engineer.

7.5.5. Construction Tolerances

The following construction tolerances shall be maintained in constructing drilled shafts:
- The drilled shaft shall be within 75 mm of the plan position in the horizontal plane at the plan elevation for the top of the shaft.
- The vertical alignment of the shaft excavation shall not vary from the plan alignment by more than 20 mm/m of depth.
- After all the shaft concrete is placed, the top of the reinforcing steel cage shall be no more than 150 mm above and no more than 75 mm below plan position.
- When casing is used, its outside diameter shall not be less than the shaft diameter shown in the contract documents. When casing is not used, the minimum diameter of the drilled shaft shall be the diameter shown in the contract documents for diameters 600 mm or less, and not more than 25 mm less than the diameter shown in the contract documents for diameters greater than 600 mm.
- The bearing area of bells shall be excavated to the plan bearing area as a minimum. All other plan dimensions shown for the bells may be varied, when approved, to accommodate the equipment used.
- The top elevation of the shaft shall be within 25 mm of the plan top of shaft elevation.
- The bottom of the shaft excavation shall be normal to the axis of the shaft within 60 mm/m of shaft diameter.
Drilled shaft excavations constructed in such a manner that the concrete shaft cannot be completed within the required tolerances are unacceptable. Correction methods shall be submitted by the Contractor for the Engineer's approval. Approval will be obtained before continuing with the drilled shaft construction.

Materials and work necessary to effect correction for out-of-tolerance drilled shaft excavations shall be furnished at no cost to the Owner.

7.6. Testing of Drilled Shafts

7.6.1. Test Shafts and Bells

Test shafts shall be constructed when required in the contract. The construction of test shafts will be used to determine if the methods, equipment, and procedures used by the Contractor are sufficient to produce a shaft excavation which meets the requirements of the plans and specifications. Production shaft construction shall not be started until the required test shaft(s) has been successfully completed.

The Contractor shall revise his methods and equipment as necessary at any time during the construction of the test shaft hole to satisfactorily complete the excavation.

The location of the test shaft shall be as shown on the plans, or as directed by the Engineer. The diameter and depth of the test shaft excavation shall be the same diameter and depth as the production drilled shafts shown on the plans. The test shaft holes shall be filled with concrete in the same manner that production shaft will be constructed unless a different backfill material is shown on the plans.

When the Contractor fails to satisfactorily demonstrate the adequacy of his methods, procedures or equipment, additional test shafts shall be provided at no additional cost to the MOMRA, until a successful test shaft has been constructed in accordance with the Engineer approved construction methods.

When shown on the plans, the reaming of bells at specified test shaft holes will be required to establish the feasibility of belling in a specific soil strata.

7.6.2. Drilled Shaft Load Tests

Loading tests are performed for two general reasons:

- to prove that the test shaft is capable of sustaining an axial load (or, sometimes, a lateral load) of a given magnitude ("proof test"), and
- to gain detailed information on load transfer in side and base resistance, or lateral performance, to allow for an improved design ("load transfer test").

When the contract documents include load testing, all tests shall be completed before construction of any production drilled shafts. The Contractor shall allow a time gap of two weeks after the last load test for the analysis of the load test data by the Engineer before specified drilled shaft tip elevations will be provided for production shafts.

The locations of load test shafts and reaction shafts, the maximum loads to be applied, the test equipment to be furnished by the Contractor, and the actual performance of the load testing shall be as shown on the plans or specified in the special provisions.

Testing of drilled shaft and pile groups shall be done according to ASTM D-1143 (for axial loading) and ASTM D-3966 (for lateral loading).
After testing is completed, the test shafts and any reaction shafts, if not also to be used as production shafts, shall be cut off at an elevation 1 m below the finished ground surface. The portion of the shafts cut off shall be disposed by the Contractor.

7.6.3. Integrity Testing

When shaft concrete is placed by the wet construction method, and when called for in the contract documents, the completed shaft will be subjected to nondestructive testing (see Article 7.6.4, "Non-destructive Testing of Drilled Shafts") to determine the extent of any defects that may be present in the shaft.

Work and materials required for testing which are to be furnished by the Contractor shall be as specified in the contract document.

In the event testing discloses voids or discontinuities in the concrete which indicate that the drilled shaft is not structurally adequate as determined by the Engineer, the shaft shall be rejected and the construction of additional drilled shafts shall be suspended until the Contractor repairs, replaces, or supplements the defective work and the Engineer approves the remedial work. Suspension of drilled shaft construction shall remain in effect until written changes pertinent to the methods of drilled shaft construction are approved by the Engineer.

7.6.4. Nondestructive Testing of Drilled Shafts

7.6.4.1. General

Crosshole Sonic Logging (CSL) testing shall be provided to check the integrity of concrete drilled shafts when CSL testing is required by the contract documents, i.e., shown in the bid schedule. If CSL access tubes are required by the contract document but CSL testing was not required by the contract documents and, in the opinion of the Engineer, a construction problem was observed during shaft construction, the Department will conduct CSL testing. If access tubes were not specified or installed, the Engineer may require full depth coring to determine the soundness of a questionable drilled shaft.

7.6.4.2. NDT Consultant

When CSL testing is required by the contract documents, the Contractor shall provide a Nondestructive Testing (NDT) consultant experienced in CSL testing. The resumes of the consulting personnel shall be submitted for approval by Engineer before testing. All CSL testing shall be performed and analyses under the supervision of a Professional Engineer. The consultant shall have a minimum of one year experience in field testing and analyzing CSL testing.

7.6.4.3. Testing Schedule

The Contractor shall wait at least 24 hours after the placement of all concrete in a shaft before CSL testing. After placement of concrete, CSL testing shall be finished within 30 days for steel access tubes.

7.6.4.4. CSL Test Equipment

The CSL test equipment used shall be capable of performing the following functions:

- Displaying individual CSL records, recording CSL data, and analyzing receiver responses,
- Printing of CSL logs,
- Testing in 50 mm I.D. access tubes,
- Generating an ultrasonic voltage pulse to excite the source with a synchronized triggering system to start the recording system,
- Measuring and recording the depths of CSL probes at the time signals are recorded,
- Filtering/amplifying signals.

7.6.4.5. CSL Logging Procedures

All perimeter tube pairs and major diagonal tube pairs shall be tested. If a possible defect is indicated, CSL testing shall be conducted between additional pairs of tubes as determined by the NDT consultant.

CSL tests shall be performed with the source and receiver probes in the same horizontal plane unless test results indicate potential defects. Angled tests consisting of the source and receiver vertically offset in the access tubes may be made to further evaluate a questionable zone. CSL measurements shall be made at depth intervals of 50 mm. Probes shall be pulled, starting from the bottom of the tubes, over a depth-measuring device. Any slack shall be removed from the cables before pulling to provide accurate depth measurements. The Contractor shall report to the Engineer any indicated defects and conduct further tests as required to evaluate the extent of such defects.

7.6.4.6. CSL Testing Results

The Contractor shall provide a preliminary report to the Engineer within 72 hours after the CSL testing has been finished and furnish, within 10 working days of testing, two copies of the final CSL testing report sealed by the Professional Engineer supervising the testing. The final report shall include:
- CSL logs with analyses of the initial pulse arrival time versus depth and pulse energy/amplitude versus depth.
- Summary of the CSL test results which covers drilled shaft identification, test date, shaft age at time of CSL testing (days from concrete placement to CSL testing), drilled shaft diameter, number of CSL tubes tested, test length, average compression velocity, and a description of defects detected.

The Contractor shall present a CSL log for each tube pair tested with any defect zones indicated on the logs and discussed in the test report as appropriate. In each defect description, the CSL tube shall include number, depth below top of concrete, percent concrete wave speed reduction, and recommended concrete condition rating.

The Engineer will evaluate the CSL test results and determine whether the drilled shaft construction is acceptable.

7.6.4.7. Core Drilling of Drilled Shaft Concrete

If a drilled shaft is believed to be unacceptable, the Engineer may require continuous coring of the shaft as specified in ASTM D 2113 Specifications. The number, depth, and location of cores will be determined by the Engineer. The Contractor shall submit the methods and equipment to be used to core the drilled shaft and grout the cored hole to the Engineer for approval before coring.

The cores shall be placed in a crate and properly mark showing the shaft depth at each interval of core recovery. The Contractor shall submit the cores and an accurate log for each core recovered. The construction above the drilled shaft in question shall
not be preceded until the quality of the concrete in the shaft, as represented by the core samples, is determined to be acceptable and notification to continue construction is given by the Engineer. If the quality of the concrete in a drilled shaft is determined to be unacceptable, then the drilled shaft will be considered defective.

### 7.6.4.8. Abandoning CSL Access Tubes

After completing CSL testing and the Engineer has approved continuing construction above the shafts, the access tubes in the drilled shafts shall be dewatered and grouted with Portland cement. The grout mix design and grouting method shall be submitted for approval.

### 7.7. Works Acceptance

All materials and works should be controlled according to the requirements of the section 3.6, "control and acceptance of materials and work", and for work acceptance, Contractor shall apply quality control for piling work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in this general specifications and other contract documents.

The Ministry shall apply quality assurance and verify the Contractor quality control procedures either through direct supervision or by carrying out neutrally quality assurance procedures using test on representative samples and in adequate numbers to judge about the quality level and accept or reject the executed works according to the principles detailed mentioned bellow in next paragraphs.

### 7.7.1. Quality Control

#### 7.7.1.1. Driven Piles

All materials used in manufacturing the piles, should be checked and insure that are fulfill the required specifications, in addition to the casting and procedure of the manufacturing which should comply with the requirements of article 7.3.1, also the process of driven piles construction and used equipments should be inspected step by step to insure that the construction methods and used equipments are satisfying the quality requirements which mention in article 7.4, and performing the load test to determine the nominal resistance of the piles according to the article 7.4.4.

#### 7.7.1.2. Drilled Shafts

All materials used in manufacturing the drilled shaft piles (concrete, reinforcement, and casting), should be checked and insure that are fulfill the required specifications mentioned in the article 7.3.2, and performing the required tests stipulated in above mentioned section and Table 7.11.

The quality control inspection should be implementation on the construction of the drilled shaft piles and the methods of establishing it in accordance with the requirements of article 7.5, including taking into consideration the limits of tolerance in the construction mentioned in article 7.5.5, as the required tests have to be performed to make assurance that the piles has reached its required nominal resistance in accordance with item 7.6 and the condition in Table 7.11.
7.7.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of materials and the constructed works through carrying out or ordering others to carry out under its supervision the tests on the piles and measurements for piling works according to the quality requirement of the article 7.3, 7.4 and 7.5 and the test stipulated in the Table 7.11.

7.8. Measurement and Payment

7.8.1. Measurement

Measurement of piles may be done by linear meter for lengths specified in the contract documents or it may be detailed as follows:

7.8.1.1. Driven Piles

1. Piles Furnished

The quantities of pile to be paid for shall be the sum of the lengths in meters. The piles shall be of the types and lengths indicated in the contract documents or ordered in writing by the Engineer, furnished in compliance with the material requirements of these Specifications and stockpiled or installed in good condition at the site of the work by the Contractor, and accepted by the Engineer.

When extensions of piles are necessary, the extension length ordered in writing by the Engineer shall be included in the total length of piling furnished.

2. Driven Piles

The quantities of driven piles of each type to be paid for shall be the quantities of acceptable piles of each type that were driven.

7.8.1.2. Pile Splices and Pile Shoes

Where pile splices or protective pile tip shoes are shown in the contract documents, the number of pile splices or shoes measured for payment shall be those shown in the contract documents, or ordered in writing by the Engineer, and actually installed on piles used in the work. No payment shall be made for splices or shoes used at the option of the Contractor. When not shown in the contract documents, pile splices or shoes ordered by the Engineer shall be paid for as extra work.

7.8.1.3. Drilled Shaft

Drilled shafts, completed in place, will be measured by the linear meter for each size of shaft listed in the contract documents. Measurement will be along the centerline of the shaft based on the tip and shaft cut-off elevations shown on the contract documents or ordered by the Engineer.

7.8.1.4. Bell Footings

Bell footings will be measured by the cubic meter, computed by using the dimensions and shape specified in the contract documents or as revised in diameter by the Engineer. The bell shall consist of the volume outside the plan or authorized dimensions of the shaft, which will extend to the bottom of the bell for the purpose of measurement.
7.8.1.5. Test shafts

Test shafts of the specified diameter will be measured from the elevation of the ground at the time drilling begins, by the linear meter of acceptable test shaft drilled.

7.8.1.6. Test Bells

Test bells will be measured by the cubic meter computed by using the dimensions specified in above Article 7.8.1.4, "Bell Footings".

7.8.1.7. Exploration

Exploration holes will be measured by the linear meter measured from the bottom of shaft elevation to the bottom of the exploration hole, for each authorized hole drilled.

7.8.1.8. Permanent Casing

Permanent casing will be measured by the linear meter for each size of casing authorized to be used. Measurement will be along the casing from top of casing or top of shaft, whichever is lower, to the bottom of the casing at each shaft location where permanent casing is authorized and used.

7.8.1.9. Load Tests

Load tests will be measured by the number of load tests performed for each designated pile load capacity.

Test piles for static load tests, whether incorporated into the permanent structure or not, shall be measured as provided for the test piles furnished and test piles driven and shall be paid for under the appropriate pay item.

7.8.2. Payment

Payment for piles may be taken to include full compensation for all costs involved or as detailed the articles below. Any additional work approved by the Engineer shall be paid separately.

7.8.2.1. Driven Piles

1. Unit Cost Contracts

The quantities, determined as specified, shall be paid for at the contract documents price per unit of measurement, respectively, for each of the general pay items listed below, for each size and type of pile shown in the contract documents as shown in the Table 7.7.

<table>
<thead>
<tr>
<th>Pay item</th>
<th>Pay Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobilization and Demobilization</td>
<td>Lump Sum</td>
</tr>
<tr>
<td>Piles Furnished</td>
<td>LM or Each</td>
</tr>
<tr>
<td>Piles Driven</td>
<td>LM or Each</td>
</tr>
<tr>
<td>Test Piles, Furnished</td>
<td>LM or Each</td>
</tr>
<tr>
<td>Test Piles, Driven</td>
<td>LM or Each</td>
</tr>
</tbody>
</table>
Payment for piles furnished shall be taken to include full compensation for all costs involved in the furnishing and delivery of all piles to the project site.

Payment for piles driven shall be taken to include full compensation for all costs involved in the actual driving and for all costs for which compensation is not provided under other specified pay items involved with the furnishing of labor, equipment, and materials used to install the piles.

Payment for static or dynamic tests shall be taken to include full compensation for providing labor, equipment, and materials needed to perform the load tests as specified. If the dynamic pile test requires substantial repositioning or idle time of the crane, additional compensation for out-of-sequence moves shall be paid at the bid rate for this item.

Payment for pile splices, shoes, or lugs shall be taken to include full compensation for all costs involved with furnishing all materials and performing the work involved with attaching or installing splices, shoes, or lugs to the piles.

Payment for pre-drilling, jetting, or spudding shall be taken to include full compensation for providing labor, equipment, and materials needed to perform these pile installation aid procedures.

Payment for cut-off shall be taken to include full compensation for providing labor and equipment needed to adapt the pile top to the specified cut-off elevation and to properly dispose of the removed material.

Payment for delays or downtime shall be taken to include full compensation for unproductive time caused by the owner, his agent, or his subcontractor.

### 2. Lump Sum Contracts

Payment shall be a lump sum for the piles as specified in the contract documents.

There shall be no change in contract price if the specified pile does not drive to the plan-tip elevation due to refusal caused by soil strata or obstructions.

---

<table>
<thead>
<tr>
<th>Pay item</th>
<th>Pay Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static Pile Load Test</td>
<td>Each</td>
</tr>
<tr>
<td>Dynamic Pile Test (during driving)</td>
<td>Each</td>
</tr>
<tr>
<td>Dynamic Pile Test (during restrike)</td>
<td>Each</td>
</tr>
<tr>
<td>Splices</td>
<td>Each</td>
</tr>
<tr>
<td>Pile Shoes</td>
<td>Each</td>
</tr>
<tr>
<td>Pre-drilling or Pre-augering</td>
<td>LM or Each</td>
</tr>
<tr>
<td>Jetting</td>
<td>LM or Each</td>
</tr>
<tr>
<td>Cut-off (over 5.0 ft lengths only)</td>
<td>Each</td>
</tr>
<tr>
<td>Spudding (Punching)</td>
<td>Per Hr.</td>
</tr>
<tr>
<td>Delays, Downtime, or Out-of-Sequence Moves</td>
<td>Per Hr.</td>
</tr>
</tbody>
</table>

*Note: LM = linear meter*
The bid form shall include the following items to accommodate changes in pile quantities. If the Engineer determines that pile lengths or number of piles are to be changed, the lump sum shall be adjusted as mentioned below in Table 7.8.

Table 7.8: Show Adjusted Measurement Unit of the Driven Piles

<table>
<thead>
<tr>
<th>Pay item</th>
<th>Pay Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase (Add)</td>
<td></td>
</tr>
<tr>
<td>Longer piles, up to 1.5 m</td>
<td>LM</td>
</tr>
<tr>
<td>Longer piles, 1.8 to 3 m</td>
<td>LM</td>
</tr>
<tr>
<td>Decrease (Deduct)</td>
<td></td>
</tr>
<tr>
<td>Shorter piles, up to 1.5 m</td>
<td>LM</td>
</tr>
<tr>
<td>Shorter piles, 1.8 to 3 m</td>
<td>LM</td>
</tr>
<tr>
<td>Increase (Add)</td>
<td></td>
</tr>
<tr>
<td>Added piles</td>
<td>Each</td>
</tr>
<tr>
<td>Decrease (Deduct)</td>
<td></td>
</tr>
<tr>
<td>Deleted piles</td>
<td>Each</td>
</tr>
</tbody>
</table>

Added or deleted piles apply only up to ten percent (10%) of the original quantity. Changes greater than this shall require a change in the unit prices. Pile length changes of more than 3 m shall require renegotiation of the contract.

If changes occur during driving, unanticipated work shall be paid as an extra.

7.8.2.2 Drilled Shafts

1. Drilled Shaft

Drilled shafts will be paid as stated in the contract price per linear meter for drilled shaft of the diameter specified. Such payment shall be considered to be full compensation for all costs involved with shaft excavation, disposal of excavated material, and the furnishing and placing of concrete and reinforcing steel, including all labor, materials, equipment, temporary casing, and incidentals necessary to complete the drilled shafts.

2. Bell Footings

Bell footings constructed to the specified or authorized dimensions will be paid as stated in the contract unit price per cubic meter for bell footings. Such payment shall include full compensation for excavation, and concrete beyond the diameter of the drilled shaft including all labor, materials, equipment and incidentals necessary to complete the bell footings.

3. Test Shafts

Test shafts of the specified diameter will be paid as per the contract unit price per linear meter for test shafts. Such payment shall include full compensation for excavation and concrete or backfill material including all labor, materials, equipment, and incidentals necessary to complete the test shafts.
4. Test Bells

Test bells of the diameter and shape specified or authorized and approved will be paid as per the contract unit price per cubic meter for test bells. Such payment shall be full compensation for excavation and concrete or backfill material including all labor, materials, equipment, and incidentals necessary to complete the test bells.

5. Exploration Holes

Exploration holes will be paid as per the contract unit price per linear meter for exploration holes. Such payment shall be full compensation for drilling or coring the holes, extracting and packaging the samples or cores and delivering them to the Department and all other expenses necessary to complete the work.

6. Permanent Casing

Permanent casing will be paid as per the contract unit price per linear meter for permanent casing. Such payment shall include full compensation for furnishing and placing the casing, above the costs attributable to the work paid for under associated pay items.

7. Load Tests

Load tests will be paid as per the contract unit price for each load test. Such payment shall include full compensation for all costs related to the performance of the load tests.

Payment will be made under one or more of the items in Table 7. Quality control requirements for piling are shown in Table 7.10.

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.4.1</td>
<td>Driven Pile</td>
<td>Lm or Each</td>
</tr>
<tr>
<td>7.4.2</td>
<td>Static Pile Load Test</td>
<td>Each</td>
</tr>
<tr>
<td>7.4.3</td>
<td>Dynamic Pile Test (During Driving)</td>
<td>Each</td>
</tr>
<tr>
<td>7.5.1</td>
<td>Drilled Shafts</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>7.5.2</td>
<td>Bell Footings</td>
<td>Cubic Meters</td>
</tr>
<tr>
<td>7.5.3</td>
<td>Test Shafts</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>7.5.4</td>
<td>Test Bells</td>
<td>Cubic Meters</td>
</tr>
<tr>
<td>7.5.5</td>
<td>Exploration holes</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>7.5.6</td>
<td>Permanent casing</td>
<td>Linear Meter</td>
</tr>
</tbody>
</table>
### Table 7.10: Quality Control Requirements For Piling

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving Heaved Piles</td>
<td>Depends on which dominating bearing or fraction</td>
<td>Measurement</td>
<td>In situ</td>
<td>Each</td>
<td>Article 7.4.3.1</td>
</tr>
<tr>
<td>Accuracy of Driving</td>
<td>a variation of not more than (1:50) from the vertical</td>
<td>Measurement</td>
<td>In situ</td>
<td>Each</td>
<td>Article 7.4.3.6</td>
</tr>
<tr>
<td>Static Load Tests</td>
<td>Determination of nominal resistance</td>
<td>Static measurement</td>
<td>In situ</td>
<td>Each</td>
<td>Article 7.4.4.2</td>
</tr>
<tr>
<td>Dynamic Testing</td>
<td>Determination of nominal resistance</td>
<td>Dynamic measurement</td>
<td>In situ</td>
<td>Each</td>
<td>Article 7.4.4.3</td>
</tr>
<tr>
<td>Trial Drilled Shafts</td>
<td>For several purposes</td>
<td>By drilling</td>
<td>As shown on the plans</td>
<td>As noted in the contractor documents</td>
<td>Article 7.5.3.1</td>
</tr>
<tr>
<td>Testing of Drilled Shafts</td>
<td>Test shafts and bells</td>
<td>By drilling</td>
<td>As shown on the plans or as directed by the Engineer</td>
<td>As directed by the Engineer</td>
<td>Article 7.6.1</td>
</tr>
<tr>
<td></td>
<td>Specified in the special provisions</td>
<td>by drilling</td>
<td>As directed by the Engineer</td>
<td>Article 7.6.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Location of testing drilled shafts</td>
<td>As directed by the Engineer</td>
<td>Article 7.6.3 and article 7.6.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nondestructive testing of drilled shafts</td>
<td>Disinterested nondestructive testing (NDT)</td>
<td>Location of testing drilled shafts</td>
<td>As directed by the Engineer</td>
<td>Article 7.6.4</td>
<td></td>
</tr>
</tbody>
</table>
Table 7.11: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>As specified</td>
<td>AASHTO M 183</td>
<td>ASTM A 36</td>
<td>Standard Specification for Carbon Structural Steel</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO M 270</td>
<td>ASTM A709</td>
<td>Standard Specification for Structural Steel for Bridges</td>
</tr>
<tr>
<td>As specified</td>
<td></td>
<td>ASTM A 252</td>
<td>Standard Specification for Welded and Seamless Steel Pipe Piles</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO M36</td>
<td>ASTM A148/ A148 M Grade 90-60</td>
<td>Standard Specification for Steel Castings, High Strength, for Structural Purposes</td>
</tr>
<tr>
<td>As specified</td>
<td></td>
<td>ASTM A36/A36M</td>
<td>Standard Specification for Carbon Structural Steel</td>
</tr>
<tr>
<td>As procedures of the test</td>
<td></td>
<td>ASTM D 3689</td>
<td>Standard Test Methods for Deep Foundations under Static Axial Tensile Load</td>
</tr>
<tr>
<td>As procedures of the test</td>
<td></td>
<td>ASTM D 3966</td>
<td>Standard Test Methods for Deep Foundations under Lateral Load</td>
</tr>
<tr>
<td>As procedures of the test</td>
<td></td>
<td>ASTM D 4945</td>
<td>Standard Test Method for High-Strain Dynamic Testing of Piles</td>
</tr>
<tr>
<td>As procedures of the test</td>
<td></td>
<td>ASTM D 2113</td>
<td>Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation</td>
</tr>
<tr>
<td>As procedures of the test</td>
<td>AASHTO T 141</td>
<td></td>
<td>Standard Method of Test for Sampling Freshly Mixed Concrete</td>
</tr>
<tr>
<td>As procedures of the test</td>
<td>AASHTO T 119</td>
<td></td>
<td>Standard Method of Test for Slump of Hydraulic Cement Concrete</td>
</tr>
</tbody>
</table>
7.9. References


Oklahoma -1999. Sec. 500 & 516 “Oklahoma Department of Transportation Standard Specifications for Highway Construction”

"AASHTO LRFD Bridges Construction Specifications"-2004. Sec. 4 & 5


MOT KSA;"General Specifications For Road And Bridge Construction"; November 1998.

MOMRA: *Kingdom of Saudi Arabia Ministry of Municipal & Rural Affairs Deputy Ministry for Technical Affairs –"Bridges Design Specifications (MA-100-D-V1/2 & V2/2)";2011."
SECTION 8. GROUND ANCHORS

8.1. Description
This work shall consist of designing, furnishing, installing, testing, and stressing permanent cement-grouted ground anchors in accordance with the contract documents, these specifications, and the contract documents.

Typical applications of Structural Systems Ground Anchors include:
- Retaining structure tie backs, - Dam stabilization,
- Resistance of uplift forces, - Tension foundations,
- Slope stabilization, - Soil nailing (bar type anchors).
- Underground structures,

8.1.1. Definitions
Alignment Load (AL) The nominal minimum load applied to an anchor during testing to keep the testing equipment positioned correctly.
Anchor Devices The anchor head wedges or nuts that grip the prestressing steel.
Anchor Head The device by which the prestressing force is permanently transmitted from the prestressing steel to the bearing plate.
Anchorage The combined system of anchor head, bearing plate, trumpet and anchorage corrosion protection that is used to transmit the prestressing force from the prestressing steel to the surface of the ground or the supported structure.
Bearing Plate The steel plate that evenly distributes the ground anchor force to the Structure.
Bond Length The length of the ground anchor that is bonded to the ground and transmits the tensile force to the soil or rock.
Centralizer The device to support and position the tendon in the drill hole so that a minimum grout cover is provided.
Coupler The means by which the prestressing force can be transmitted from one partial-length of prestressing tendon to another.
Design Load (DL) The anticipated final maximum effective load in the anchor after allowance for time-dependent losses or gains. The design load includes appropriate load factors to ensure that the overall structure has adequate capacity for its intended use.
Free Stressing (unbonded) Length The designed length of the tendon that is not bonded to the surrounding ground or grout during stressing.
<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ground Anchor</strong></td>
<td>A system, referred to as a tieback or as an anchor, used to transfer tensile loads to soil or rock. A ground anchor includes all prestressing steel, anchorage devices, grout, coatings, sheathings and couplers if used.</td>
</tr>
<tr>
<td><strong>Lift-Off Load</strong></td>
<td>Checking the load (lift-off load) in the tendon at any specified time with the use of hydraulic jack, by lifting the anchor head off the bearing plate.</td>
</tr>
<tr>
<td><strong>Lock-Off Load</strong></td>
<td>The prestressing force in an anchor immediately after transferring the load from the jack to the stressing anchorage.</td>
</tr>
<tr>
<td><strong>Maintaining Consistency of Load</strong></td>
<td>Maintaining the test load within 5-percent of the specified value.</td>
</tr>
<tr>
<td><strong>Minimum Guaranteed Ultimate Tensile Strength (MUTS)</strong></td>
<td>The minimum guaranteed breaking load of the prestressing steel as defined by the specified standard.</td>
</tr>
<tr>
<td><strong>Performance Test</strong></td>
<td>The incremental cyclic test loading of an anchor, while recording the total movement of the anchor at each increment, including alignment load.</td>
</tr>
<tr>
<td><strong>Permanent Anchor</strong></td>
<td>Any prestressed anchor intended for permanent use, generally with more than a 24-month service life.</td>
</tr>
<tr>
<td><strong>Post-Grouting</strong></td>
<td>Regrouting an anchor after the primary grout has set.</td>
</tr>
<tr>
<td><strong>Prestressing Steel</strong></td>
<td>Strands, a group of strands combined to form a tendon or a high strength steel bar.</td>
</tr>
<tr>
<td><strong>Primary Grout</strong></td>
<td>Portland cement based grout that is injected into the anchor hole prior to or after the installation of the anchor tendon to provide for the force transfer to the surrounding ground along the bond length of the tendon.</td>
</tr>
<tr>
<td><strong>Proof Test</strong></td>
<td>Incremental loading of an anchor, and recording the total movement of the anchor at each increment.</td>
</tr>
<tr>
<td><strong>Temporary Anchor</strong></td>
<td>Prestressed anchor intended for temporary use, generally with less than a 24-month service life. Temporary anchors installed in corrosive environments may require corrosion protection.</td>
</tr>
<tr>
<td><strong>Test Anchor</strong></td>
<td>An anchor installed prior to the installation of the production anchors and then loaded to verify the design parameters.</td>
</tr>
<tr>
<td><strong>Test Load (TL)</strong></td>
<td>The maximum load to which the anchor is subjected during testing.</td>
</tr>
<tr>
<td><strong>Total Anchor Length</strong></td>
<td>The unbonded length plus the tendon bond length.</td>
</tr>
</tbody>
</table>
8.2. Submission and Design Requirements

8.2.1. Contractor Qualifications

The Contractor or Subcontractor performing this work shall have installed permanent ground anchors for a minimum of three years. Prior to the beginning of construction, the Contractor shall submit a list containing at least five projects on which the Contractor has installed permanent ground anchors. A brief description of each project and a reference shall be included for each project listed. As a minimum, the reference shall include an individual’s name and current phone number.

The Contractor shall assign an engineer to supervise the work with at least three years of experience in the design and construction of permanently anchored Structures. The Contractor shall not use consultants or manufacturer’s representatives in order to meet the requirements of this section. Drill operators and on-site supervisors shall have a minimum of one year experience installing permanent ground anchors.

The Contractor shall allow up to fifteen days for the Engineer to review the qualifications and staff as noted above. Work shall not be started on any anchored wall system nor are materials ordered until approval of the Contractor’s qualifications given.

8.2.2. Working Drawings

At least four weeks before work is to begin, the contractor shall submit to the Engineer for review and approval complete working drawings and design calculations describing the ground anchors system or systems intended for use. The submittal shall include the following:

1. A ground anchor schedule giving:
2. Ground anchor number
3. Ground anchor design load
4. Type and size of tendon
5. Minimum total anchor length
6. Minimum bond length
7. Minimum tendon bond length and
8. Minimum unbonded length

A drawing of the ground anchor tendon and the corrosion protection system, including details for the following:

1. Spacers separating elements of tendon and their location;
2. Centralizers and their location;
3. Unbonded length corrosion protection system;
4. Bond length corrosion protection system;
5. Anchorage and trumpet;
6. Anchorage corrosion protection system;
7. Drilled for formed hole size;
8. Level of each stage of grouting;

Any revisions to structure details necessary to accommodate the ground anchor system intended for use.

The grout mix design and procedures for placing the grout.
The Engineer shall review and approve or show basis reasons for rejecting the Contractor's working drawings within four weeks of receipt of a complete submittal. No work on ground anchors shall begin until working drawings have been approved in writing by the Engineer. Such approval shall not relieve the Contractor of any responsibility under the contract for the successful completion of the work.

8.3. Materials

8.3.1. Prestressing Steel

Grouted anchors tendons shall consist of single or multiple elements of prestressing steel, anchorage devices and, if required, couplers conforming to the requirements described in Section 12, "Prestressing" in these specifications. The following materials are acceptable for use as ground anchor tendons:

- AASHTO: M 203M/M 203 (ASTM A 416/A 416 M uncoated, 7–wire strand)
- ASTM: A 886/A 886M (indented, 7 – wire strand)
- ASTM: A 882/A 882M (Epoxy coated, 7 – wire strand)
- SASO: Saudi Arabian Standard Organization

8.3.2. Grout

Cement shall be Type I, II, or III Portland Cements conforming to AASHTO M 85 (ASTM C 150). Cement used for grouting shall be fresh and shall not contain any lumps or other indications of hydration or "pack set".

Aggregates shall conform to the requirements for fine aggregate described in section 7 "Concrete Structure".

Admixtures may be used in the grout subject to the approval of the Engineer. Expansive admixture may only be added to the grout used for filling sealed encapsulations, trumpets, and anchorage covers. Accelerator admixtures shall not be used.

Water for mixing grout shall be potable, clean and free of any quantities of substances known to be harmful to Portland cement or prestressing steel.

8.3.3. Steel Elements

Bearing plates shall be fabricated from steel conforming to AASHTO M 270 (ASTM A 709) Grade 250 as a minimum, or be a ductile iron casting conforming to ASTM A 536.

Trumpets used to provide a transition from the anchorage to the unbonded length corrosion protection shall be fabricated from a steel pipe or tube conforming to the requirements of ASTM A 53 for pipe or ASTM A 500 for tubing. Minimum wall thickness shall be 5 mm.

Anchorage covers used to enclose exposed anchorages shall be fabricated from steel, steel pipe, steel tube, or ductile cast iron conforming to the requirements of AASHTO M 270 (ASTM A 709) Grade 36 for steel, ASTM A 53 for pipe, ASTM A 500 for tubing, and ASTM A 536 for ductile cast iron. Minimum thickness shall be 3 mm.
8.3.4. Corrosion Protection Elements

Corrosion inhibiting grease shall conform to the requirements of Specifications for Unbonded Single Strand Tendons or equivalent.

Sheath for the unbonded length of a tendon shall consist one of the following:

- Seamless polyethylene (PE) tube having a minimum wall thickness of 1.5 mm ±0.25 mm. Polyethylene shall be classified by ASTM D 3350.
- Seamless polypropylene tube having a minimum wall thickness of 1.5 mm ±0.25 mm. Polypropylene shall be classified by ASTM D 4101.
- Heat-shrinkable tube consisting of a radiation cross-linked polyolefin tube internally coated with an adhesive sealant. The minimum tube wall thickness before shrinking shall be 0.6 mm. The minimum adhesive sealant thickness shall be 0.5 mm.
- Corrugated polyvinyl chloride (PVC) tube having a minimum wall thickness of 0.8 mm.

Encapsulation for the tendon bond length shall consist of one of the following:

- Corrugated high density polyethylene (HDPE) tube having a minimum wall thickness of 0.8 mm and conforming to AASHTO M 252 requirements.
- Deformed steel tube or pipe having a minimum wall thickness of 0.65 mm.
- Corrugated polyvinyl chloride (PVC) tube having a minimum wall thickness of 0.8 mm.
- Fusion–bonded epoxy conforming to the requirements of AASHTO M 317M/M317 (ASTM D3963/D 3963M) expect that it shall have a film thickness of 0.4 mm.

8.3.5. Miscellaneous Elements

Bond-breaker for a tendon shall consist of smooth plastic tube or pipe that is resistant to aging by ultraviolet light and that is capable of withstanding abrasion, impact and bending during handling and installation.

Spacers for separation of element of a multi–element tendon shall permit the free flow of grout. They shall be fabricated from plastic, steel, or material which is not detrimental to the prestressing steel. Wood shall not be used.

Centralizers shall be fabricated from plastic, steel, or material which is not detrimental to either the prestressing steel, or any element of the tendon corrosion protection. Wood shall not be used. The centralizer shall be able to maintain the position of the tendon so that a minimum of 12 mm of grout cover is obtained on the tendons, or over the encapsulation.

8.4. Construction Requirements

8.4.1. Tendons Fabrication

8.4.1.1. General

Tendons can be either shop or field fabricated. The tendon shall be fabricated as shown in the approved contract documents.

The Contractor shall select the type of tendon to be used. The tendon shall be sized so:
- The design load does not exceed sixty percent (60%) of the minimum guaranteed ultimate tensile strength of the tendon.
- The maximum test load does not exceed eighty percent (80%) of the minimum guaranteed ultimate tensile strength of the tendon.

8.4.1.2. Tendon Bond Length

The Contractor shall determine the bond length necessary to develop the design load indicated on the drawings. The minimum tendon bond length shall be 3 m in rock and 4.5 meters in soil.

The tendon bond length shall be encapsulated by a grout-filled corrugated plastic or deformed steel tube, or by a fusion-bonded epoxy coating. The tendon shall be grouted inside the encapsulation either prior to inserting the tendon in the drill hole or after the tendon has been placed in the drill hole. Punching holes in the encapsulation and allowing the grout to flow from the encapsulation to the drill hole, or vice versa, will not be permitted. The tendon shall be centralized within the encapsulation and the tube sized to provide an average of 5 mm of grout cover for the prestressing steel. For grout-protected ground anchors tendons, spacers and centralizers shall be used to satisfy the same requirements specified in Article 8.4.1.3 "Spacers and Centralizers". The anchorage device of tendons protected with fusion-bonded epoxy shall be electrically isolated from the structure.

8.4.1.3. Spacers and Centralizers

Spacers shall be placed along the tendon bond length of multi-element tendons so that the prestressing steel will bond to the grout. They shall be located at 3 m maximum centers with the upper one located a maximum of 1.5 m from the top of the tendon bond length and the lower one located a maximum of 1.5 m from the bottom of the tendon bond length.

Centralizers shall be placed along the bond length. They shall be located at 3 m maximum centers with the upper one located a maximum of 1.5 m from the top of the bond length and the lower one located 0.3 m from the bottom of the bond length. Centralizers are not required on tendons installed utilizing a hollow-stem auger if it is grouted through the auger and the drill hole is maintained full of a stiff grout (0.23 m slump or less) during extraction of the auger. A combination centralizer-spacer may be used.

Centralizers are not required on tendons installed utilizing a pressure injection system in coarse-grained soils using grouting pressures greater than 1 MPa.

Centralizers shall be used to insure a minimum of 13 mm of grout cover over the tendon bond length or tendon bond length encapsulation as appropriate.

The Contractor shall use centralizers that do not impede the free flow of grout up the bore hole.

Centralizers shall be positioned so their center-to-center spacing does not exceed 3 meters.

8.4.1.4. Unbonded Length

The Contractor shall provide minimum unbonded length of 4.5 meters.

1. If the entire drill hole is grouted in one operation, the Contractor shall provide corrosion protection of the unbonded length with a sheath completely filled with
corrosion inhibiting grease or grout, or a heat shrinkable tube internally coated with an elastic adhesive.

If grease is used under the sheath, the Contractor shall:

- Completely coat the unbounded tendon length;
- Fill spaces between individual elements of multi-element tendon with grease;
- Provide measures to prevent grease from escaping at the ends of the sheath.

If the sheath is grout filled, a separate bondbreaker shall be provided along the unbonded length of the tendon.

2. If a grease-filled sheath corrosion protection is provided and the drill hole above the bond length is grouted after the ground anchor is locked off, the contractor shall grout the tendon inside a second sheath.

Where re-stressable ground anchors are used, the contractor shall provide a re-stressable anchorage compatible with the post-tensioning system provided.

If multi-element tendons are used, the wedges shall be seated properly as recommended for the post-tensioning system provided.

8.4.1.5. Bearing Plates, Anchorage and Trumpet

Anchorage systems that are less amenable to re-stressing may be used unless restressable anchorages are designated on the contract documents or specified in the contract documents.

Bearing plates shall be sized so that the bending stresses in the plate and average bearing stress on the concrete, if applicable, do not exceed the allowable stresses of the concrete, if applicable do not exceed the nominal resistances described in MA-100-D-V1/2, Article 5.13.6.2. The size of bearing plates shall not be less than that shown on the contract documents or on the approved working drawings.

The trumpet shall be welded to the bearing plate. The trumpet shall have an inside diameter at least 6 mm greater than the diameter of the tendon at the anchorage. The trumpet shall be long enough to accommodate movements of the structure during testing and stressing. For strand tendons with encapsulation over the unbonded length, the trumpet shall be long enough to enable the tendons to make a transition from the diameter of the tendon in the unbonded length to the diameter of the tendon at the anchor head without damaging the encapsulation. Trumpets filled with corrosion-inhibiting grease shall have a permanent Buna-N rubber or approved equal seal provided between the trumpet and the unbonded length corrosion protection. Trumpets filled with grout shall have a temporary seal provided between the trumpet and the unbonded length corrosion protection.

8.4.1.6. Tendon Storage and Handling

Tendons shall be stored and handled in such a manner as to avoid damage or corrosion. Damage to tendon prestressing steel as a result of abrasions, cuts, nicks, welds and weld splatter will be a cause for rejection by the Engineer. Grounding of welding leads to the prestressing steel is not permitted. A slight rusting, provided it is not sufficient to cause pits visible to the unaided eye, shall not be a cause for rejection. Prior to inserting a tendon into the drilled hole, its corrosion protection elements shall be examined for damage. Any damage found shall be repaired in a manner approved by the Engineer.
Repairs to encapsulation shall be in accordance with the tendons Supplier's recommendation.

8.5. Installation
The Contractor shall select the drilling method, the grouting procedure, and grouting pressure to be used for the installation of the ground anchor as necessary to satisfy the load test requirements.

8.5.1. Drilling
The drilling method used in anchorage may be core drilling, rotary drilling, percussion drilling, and auger drilling or driven casing. The utilized method of drilling shall prevent loss of ground above the drilled hole that may be detrimental to the structure or existing structures. Casing for anchor holes, if used, shall be removed, unless permitted by the Engineer to be left in place. The location, inclination, and alignment of the drilled hole shall be as shown on the contract documents. Inclination and alignment shall be within ±3 degrees of the planned angle at the bearing plate, and within ±300 mm of the planned location at the ground surface (point of entry).

8.5.2. Tendon Insertion
The tendon shall be inserted into the drilled hole to the desired depth without difficulty. When the tendon cannot be completely inserted it shall be removed and the drill hole cleaned or re-drilled to permit insertion. Partially inserted tendons shall not be driven or forced into the hole.

8.5.3. Grouting
A neat cement grout or sand-cement grout conforming to Article 8.3.2 "Grout" shall be used. Admixtures, if used, shall be mixed in quantities not to exceed the manufacturer's recommendations.

The grouting equipment shall produce a grout free of lumps and undispersed cement. A positive displacement grout pump shall be used. The pump shall be equipped with a pressure gauge to monitor grout pressures. The pressure gauge shall be capable of measuring pressures of at least 1 MPa or twice the actual grout pressures used, whichever is greater. The grouting equipment shall be sized to enable the grout to be pumped in one continuous operation. The mixer shall be capable of continuously agitating the grout.

The grout shall be injected from the lowest point of the drill hole. The grout may be pumped through grout tubes, casing, hollow-stem augers or drill rods. The quantity of the grout and the grout pressures shall be recorded. The grout pressures and grout takes shall be controlled to prevent excessive heave of the ground or fracturing of rock formations.

Except where indicated below, the grout above the top of the bond length may be placed at the same time as the bond length grout, but it shall not be placed under pressure. The grout at the top of the drill hole shall stop 150 mm from the back of the structure or from the bottom of the trumpet, whichever is lowest.

If the ground anchor is installed in a fine grained soil using a drilled hole larger than 150 mm in diameter, then the grout above the top of the bond length shall be placed after the ground anchor has been load tested. The entire drill hole may be grouted at the same time if it can be demonstrated that the ground anchor system does not de-rive a
significant portion of its load resistance from the soil above the bond length portion of the ground anchor.

Pressure grouting techniques shall be utilized if grout protected tendons are used for ground anchors anchored in rock. Pressure grouting requires that the drill hole be sealed and that the grout be injected until a 0.35 MPa grout pressure can be maintained on the grout within the bond length for a period of five minutes.

Upon completion of grouting, the grout tube may remain in the drill hole provided it is filled with grout.

After grouting, the tendon shall not be loaded for a minimum of three days.

8.5.4. Trumpet and Anchorage

The corrosion protection surrounding the unbonded length of the tendon shall extend into the trumpet a minimum of 150 mm beyond the bottom seal in the trumpet.

The corrosion protection surrounding the unbonded length of the tendon shall not contact the bearing plate or the anchor head during load testing or stressing.

The bearing plate and anchor head shall be placed perpendicular to the axis of the tendon.

The trumpet shall be completely filled with corrosion inhibiting grease or grout. The grease may be placed any time during construction. The grout shall be placed after the ground anchor has been load-tested. The Contractor shall demonstrate that the procedures selected for placement of either grease or grout will produce a completely filled trumpet.

Anchorages not encased in concrete shall be covered with a corrosion inhibiting grease-filled or grout-filled steel enclosure.

8.6. Testing And Stressing

Each ground anchor shall be tested. The test load shall be simultaneously applied to the entire tendon. Stressing of single elements of multi-element tendons will not be permitted. The Engineer will record test data.

8.6.1. Verification Test

Verification tests will be required only when specified in the Contract documents.

8.6.2. Test Equipment

The testing equipment shall consist of:

A dial gauge or a potentiometers or vernier scale capable of measuring to 0.025 mm.

Movement measuring device having a minimum travel equal to the theoretical elastic elongation of the total anchor length at the maximum test load shall be used. A device with sufficient travel shall be used so the anchor movement is measured without resetting the device.

A hydraulic jack and pump shall be used to apply the load test. The jack and a calibrated pressure gauge or load cells shall be used to measure the applied load. The contractor shall have the jack and pressure gauge calibrated as a unit by an independent firm within 45 days of the start of ground anchor work. The pressure gauge shall be graduated in 0.7 MPa increments or less. When the theoretical elastic elongation of the total anchor length at the maximum test load exceeds the ram travel of the jack, the
pressure for recycling the jack ram shall be included on the working drawings. Each increment of test load shall be applied as rapidly as possible.

A calibrated reference gauge shall be available at the site. The reference gauge shall be calibrated with the test jack and pressure gage. An electrical resistance load cell and readout shall be provided when performing a creep test.

8.6.3. Performance Test

Five percent of the ground anchors or a minimum of three ground anchors, whichever is greater shall be performance tested in accordance with the following procedures. The Engineer shall select the ground anchors to be performance tested. The remaining anchors shall be tested in accordance with the proof test procedures.

The performance test shall be made by incrementally loading and unloading the ground anchor in accordance with the following schedule shown in Table 8.1. unless a different maximum test load and schedule are indicated in the contract document:

- The load shall be raised from one increment to another immediately after recording the ground anchor movement.
- The ground anchor movement shall be measured and recorded to the nearest 0.025 mm with respect to an independent fixed reference point at the alignment load and at each increment of load.
- The load shall be monitored with a pressure gauge.
- The reference pressure gauge shall be placed in series with the pressure gauge during each performance test.

If the load determined by the reference pressure gauge and the load determined by the pressure gauge differ by more than ten percent (10%), the jack, pressure gauge and reference pressure gauge shall be recalibrated. At load increments other than the maximum test load, the load shall be held just long enough to obtain the movement reading.

Table 8.1: Performance Test Schedule

<table>
<thead>
<tr>
<th>Load</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>AL</td>
</tr>
<tr>
<td>0.25DL*</td>
<td>0.25DL</td>
</tr>
<tr>
<td>AL</td>
<td>0.5DL</td>
</tr>
<tr>
<td>0.25DL</td>
<td>0.75DL</td>
</tr>
<tr>
<td>0.50DL*</td>
<td>1.00DL</td>
</tr>
<tr>
<td>AL</td>
<td>1.20DL*</td>
</tr>
<tr>
<td>0.25DL</td>
<td>AL</td>
</tr>
<tr>
<td>0.50DL</td>
<td>0.25DL</td>
</tr>
<tr>
<td>0.75DL*</td>
<td>0.50DL</td>
</tr>
<tr>
<td>AL</td>
<td>0.75DL</td>
</tr>
</tbody>
</table>
Where:

<table>
<thead>
<tr>
<th>Load</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25DL</td>
<td>1.00DL</td>
</tr>
<tr>
<td>0.50DL</td>
<td>1.20DL</td>
</tr>
<tr>
<td>0.75DL</td>
<td>1.33DL (Max. test load)</td>
</tr>
<tr>
<td>1.00DL*</td>
<td>Reduce to lock off load</td>
</tr>
</tbody>
</table>

The maximum test load in a performance test shall be held for 10 minutes. The jack shall be repumped as necessary in order to maintain a constant load. The load-hold period shall start as soon as the maximum test load is applied and the ground anchor movement shall be measured and recorded at 1 minute, 2, 3, 4, 5, 6, and 10 minutes. If the ground anchor movements between 1 minute and 10 minutes exceeds 1 mm, the maximum test load shall be held for an additional 50 minutes. If the load-hold is extended, the ground anchor movement shall be recorded at 15 minutes, 20, 25, 30, 45 and 60 minutes.

A graph shall be constructed showing a plot of ground anchor movement versus load for each load increment marked with an asterisk (*) in Table 8.1 and a plot of the residual ground anchor movement of the tendon at each alignment load versus the highest previously applied load. Graph format shall be approved by the Engineer prior to use.

8.6.4. Proof Test

The proof test shall be performed by incrementally loading the ground anchor in accordance with the following schedule shown in Table 8.2 unless a different maximum test load and schedule are indicated on the contract documents. The load shall be raised from one increment to another immediately after recording the ground anchor movement. The ground anchor movement shall be measured and recorded to the nearest 0.025 mm with respect to an independent fixed reference point at the alignment load and at each increment of load. The load shall be monitored with a pressure gauge. At load increments other than the maximum test load, the load shall be held just long enough to obtain the movement reading.

<table>
<thead>
<tr>
<th>Test Load</th>
<th>Design Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL</td>
<td>1.00DL</td>
</tr>
<tr>
<td>0.25DL</td>
<td>1.20DL</td>
</tr>
<tr>
<td>0.50DL</td>
<td>1.33DL (Max. Test Load)</td>
</tr>
</tbody>
</table>

Where:

| AL = Alignment load |
| DL = Design load for ground anchor |
The maximum test load in a proof test shall be held for 10 minutes. The jack shall be repumped as necessary in order to maintain a constant load. The load hold period shall start as soon as the maximum test load is applied and the ground anchor movement shall be measured and recorded at 1 minute, 2, 3, 4, 5, 6, and 10 minutes. If the ground anchor movement between 1 minute and 10 minutes exceeds 1 mm, the maximum test load shall be held for an additional 50 minutes. If the load hold is extended, the ground anchor movement shall be recorded at 15 minutes, 20, 30, 45, and 60 minutes. A graph shall be constructed showing a plot of ground anchor movement shall be at versus load for each load increment in the proof test. Graph format shall be approved by the Engineer prior to use.

### 8.6.5. Creep Test

Creep tests shall be performed if required by the contract documents or special provisions. The Engineer shall select the ground anchors to be creep tested.

The creep test shall be made by incrementally loading and unloading the ground anchor in accordance with the performance test schedule shown in Table 8.3. At the end of each loading cycle, the load shall be held constant for the observation period indicated in the creep test schedule below unless a different maximum test load is indicated on the contract documents. The times for reading and recording the ground anchor movement during each observation period shall be 1 minute, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30, 45, 60, 75, 90, 100, 120, 150, 180, 210, 240, 270, and 300 minutes as appropriate. Each load-hold period shall start as soon as the test load is applied. In a creep test the pressure gauge and reference pressure gauge will be used to measure the applied load, and the load cell will be used to monitor small changes of load during a constant load-hold period. The jack shall be repumped as necessary in order to maintain a constant load.

<table>
<thead>
<tr>
<th>AL</th>
<th>Observation Period (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25DL</td>
<td>10</td>
</tr>
<tr>
<td>0.50DL</td>
<td>30</td>
</tr>
<tr>
<td>0.75DL</td>
<td>30</td>
</tr>
<tr>
<td>1.00DL</td>
<td>45</td>
</tr>
<tr>
<td>1.20DL</td>
<td>60</td>
</tr>
<tr>
<td>1.33DL</td>
<td>300</td>
</tr>
</tbody>
</table>

A graph shall be constructed showing a plot of the ground anchor movement and the residual movement measured in a creep test as described for the performance test. Also, a graph shall be constructed showing a plot of the ground anchor creep movement for each load hold as a function of the logarithm of time. Graph formats shall be approved by the Engineer prior to use.

### 8.6.6. Lock-Off

Upon successful completion of the load testing, the ground anchor load shall be reduced to the lock-off load indicated on the contract documents and transferred to the
anchorage device. The ground anchor may be completely unloaded prior to lock-off. After transferring the load and prior to removing the jack, a lift-off load reading shall be made. The lift-off load shall be within ten percent (10%) of the specified lock-off load. If the load is not within ten percent (10%) of the specified lock-off load, the anchorage shall be reset and another lift-off load reading shall be made. This process shall be repeated until the desired lock-off load is obtained.

8.6.7. Acceptance

A performance-tested or proof-tested ground anchor with a 10 minutes load hold is acceptable if the:

Ground anchor carries the maximum test load with less than 1 mm of movement between 1 minute and 10 minutes; and

Total movement at the maximum test load exceeds eighty percent (80%) of the theoretical elastic elongation of the tendon unbonded length.

A verification, performance or proof tested ground anchor with a 60 minutes load hold is acceptable if the:

Ground anchor carries the maximum test load with a creep rate that does not exceed 2 mm/log cycle of time and is a linear or decreasing creep rate.

Total movement at the maximum test load exceeds eighty percent (80%) of the theoretical elastic elongation of the tendon unbonded length.

If the total movement of the ground anchors at the maximum test load does not exceed eighty percent (80%) of the theoretical elastic elongation of the tendon unbonded length, the Contractor shall replace the ground anchor at no additional cost to the owner. Retesting of a ground anchor will not be allowed.

Ground anchors that have a creep rate greater than 2 mm/log cycle of time can be incorporated in the finished Work at a load equal to half of its failure load. The failure load is the load carried by the anchor after the load has been allowed to stabilize for 10 minutes.

When a ground anchor fails, the Contractor shall modify the design, the construction procedures, or both. These modifications may include, but are not limited to, installing replacement ground anchors, modifying the installation methods, increasing the bond length or changing the ground anchor type. Any modification that requires changes to the Structure shall have prior approval of the Engineer. Any modifications of design or construction procedures shall be at the Contractor’s expense.

Upon completion of the test, the load shall be adjusted to the lock-off load indicated in the Contract documents and transferred to the anchorage device. The ground anchor may be completely unloaded prior to lock-off. After transferring the load and prior to removing the jack a lift-off reading shall be made. The lift-off reading shall be within ten percent (10%) of the specified lock-off load.

If the load is not within ten percent (10%) of the specified lock-off load, the anchorage shall be reset and another lift-off reading shall be made. This process shall be repeated until the desired lock-off load is obtained.

8.7. Works Acceptance

All materials and works should be controlled according to the requirements of the section 3.6, "control and acceptance of materials and work", and for work acceptance, Contractor shall apply quality control for Grouted anchors work through carrying out
all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in this general specifications and other contract documents.

The Ministry shall apply quality assurance and verify the Contractor quality control procedures either through direct supervision or by carrying out neutrally quality assurance procedures using test on representative samples and in adequate numbers to judge about the quality level and accept or reject the executed works according to the principles detailed mentioned below in next paragraphs.

8.7.1. Quality Control

The work should be controlled and inspected following the steps of work inspection starting with attending the contractor team work qualifications according to the items mentioned in articles 8.2.1 and 8.2.2, all materials used in manufacturing the work items, should be checked and insure that are fulfill the required specifications of article 8.3, and performing the required material tests to determine acceptance according to the article 8.3 and Table 8.6.

Construction process of the Grouted anchors should be inspected to insure that all construction requirements are achieved in correct manner following the instructions mentioned in the article 8.4, and supervising the installation process according the article 8.5. Work acceptance should be according to the required test results and insure that the load test of Grouted anchors is acceptable according to the article 8.6.7.

8.7.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of materials and the constructed works through carrying out or ordering others to carry out under its supervision the tests on the Grouted anchors ask for the certificates according to the quality requirement which is required to assure the quality of the work.

8.8. Measurement and Payment

Grouted anchors will be measured and paid for by the number of units installed and accepted as shown on the plans or ordered by the Engineer. No change in the number of ground anchors to be paid for will be made because of the use by the Contractor or an alternative number of ground anchors.

The contract unit price paid for ground anchors shall include full compensation for furnishing all labor, materials, tools, equipments, incidentals, and for doing all the work involved in installing the ground anchors (including testing) complete in place, as shown on the plans and as specified in these specifications and the special provisions, and as directed by the Engineer.

Payment will be made under one or more of the items in Table 8.5. Quality control requirements for ground anchors are shown in Table 8.4.
Table 8.5: Ground Anchors Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1</td>
<td>Ground Anchors</td>
<td>Each</td>
</tr>
<tr>
<td>8.6.1</td>
<td>Verification Test</td>
<td>Each</td>
</tr>
<tr>
<td>8.6.2</td>
<td>Performance Test</td>
<td>Each</td>
</tr>
<tr>
<td>8.6.3</td>
<td>Proof Test</td>
<td>Each</td>
</tr>
<tr>
<td>8.6.4</td>
<td>Creep Test</td>
<td>Each</td>
</tr>
</tbody>
</table>

Table 8.6: Quality Control Requirements For Ground Anchors

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance Test</td>
<td>Repeated loading by change load value</td>
<td>By pressure gauge</td>
<td>As directed by the engineer</td>
<td>Five percent of the ground anchors or a minimum of three ground anchors</td>
<td>Article 8.6.3 and 8.6.7</td>
</tr>
<tr>
<td>Proof Test</td>
<td>Measurement</td>
<td>Loading device</td>
<td>As directed by the engineer</td>
<td>Select by the engineer</td>
<td>Article 8.6.4 and 8.6.7</td>
</tr>
<tr>
<td>Creep Test</td>
<td>When a special provisions is needed</td>
<td>Loading device</td>
<td>As directed by the engineer</td>
<td>Select by the engineer</td>
<td>Article 8.6.4 and 8.6.7</td>
</tr>
</tbody>
</table>
### Table 8.7: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>As specified</td>
<td></td>
<td>ASTM A 416/A416 M</td>
<td>Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete.</td>
</tr>
<tr>
<td>As specified</td>
<td></td>
<td>ASTM 886/A886M</td>
<td>Standard Specification for Steel Strand, Indented, Seven-Wire Stress-Relieved for Prestressed Concrete.</td>
</tr>
<tr>
<td>As specified</td>
<td></td>
<td>ASTM A 882/A882M</td>
<td>Standard Specification for Filled Epoxy-Coated Seven-Wire Prestressing Steel Strand.</td>
</tr>
<tr>
<td>As specified</td>
<td></td>
<td>ASTM A 53</td>
<td>Tentative Specification for Welded and Seamless Steel Pipe - WITHDRAWN - Replaced by Current Revision.</td>
</tr>
<tr>
<td>As specified</td>
<td></td>
<td>ASTM A 500</td>
<td>Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.</td>
</tr>
<tr>
<td>As specified</td>
<td></td>
<td>AASHTO M 270M / M 270</td>
<td>Standard Specification for Structural Steel for Bridges.</td>
</tr>
<tr>
<td>As specified</td>
<td></td>
<td>ASTM A709/A709M</td>
<td>Standard Specification for Structural Steel for Bridges.</td>
</tr>
<tr>
<td>As specified</td>
<td></td>
<td>ASTM A53/A53M</td>
<td>Tentative Specification for Welded and Seamless Steel Pipe - WITHDRAWN - Replaced by Current Revision.</td>
</tr>
<tr>
<td>As specified</td>
<td></td>
<td>ASTM A 500</td>
<td>Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.</td>
</tr>
</tbody>
</table>
8.9. References
ACI 315, American Concrete Institute "Details and Detailing of Concrete Reinforcement" -1992.

SBC 304, Saudi building code “Structural – Concrete Structures (details of reinforcement)” -2007


"AASHTO LRFD Bridges Construction Specifications"; 2004. Sec. 10


MOMRA: Kingdom of Saudi Arabia Ministry of Municipal & Rural Affairs Deputy Ministry for Technical Affairs –"Bridges Design Specifications" (MA-100-D-V1/2 & V2/2)- 2011.
SECTION 9. EARTH RETAINING SYSTEMS

9.1. Description
This work shall consist of furnishing and installing earth retaining systems in accordance with the contract documents, and these specifications.

Earth retaining systems include concrete and masonry gravity walls, reinforced concrete walls, sheet pile and soldier pile walls (with and without ground anchors or other anchorage systems), crib and cellular walls, and mechanically stabilized earth walls.

9.2. Working Drawings
Working drawings and design calculations shall be submitted to the Engineer for review and approval at least 4 weeks before work is to begin. Such submittals shall be required in the following case:

1. For each alternative proprietary or nonproprietary earth retaining systems proposed as permitted or specified in the contract documents,
2. when complete details for the system to be constructed are not included in the contract documents, and
3. when otherwise required by the contract documents or these specifications.

Working drawings and design calculations shall include the following:

a. Existing ground elevations that have been verified by the contractor for each location involving construction wholly or partially in the original ground.
b. Layout of wall that will effectively retain the earth but not less in height or length than that shown for the wall system in the contract documents.
c. Complete design calculations submitting that the proposed design satisfies the design parameters in the contract documents.
d. Complete details of all elements required for the proper construction of the system, including complete material specifications.
e. Earthwork requirements including specifications for material and compaction of backfill.
f. Details of revisions or additions to drainage systems or other facilities required to accommodate the system.
g. Other information required in the contract documents or requested by the Engineer.

The contractor shall not start any work on earth retaining system for which working drawings are required until such drawings have been approved by the Engineer. Approval of the Contractor's working drawings shall not relieve the contractor of any of his responsibility under the contract for the successful completion of the work.
9.3. Materials

9.3.1. Concrete

9.3.1.1. Cast-in-Place
Cast-in-place concrete shall conform to the requirements of Section 10, "Concrete Structure". The concrete shall be Class A unless otherwise indicated in the contract documents.

9.3.1.2. Pneumatically Applied Mortar
Pneumatically applied mortar shall conform to the requirements of Section 23, "Pneumatically Applied Mortar".

9.3.1.3. Precast Elements
The material, manufacturing, storage, handling, and erection of precast concrete elements shall conform to the requirements in Article 10.15, "Precast Concrete Members" in Section 10, "Concrete Structures". Unless otherwise shown on the contract documents or on the approved working drawings, Portland cement concrete used in precast elements shall conform to Class A with a minimum compressive strength at 28 days of 28 MPa.

9.3.1.4. Segmental Concrete Facing Blocks
Masonry concrete blocks used as wall-facing elements shall have a minimum compressive strength of 28 MPa and a water absorption limit of five percent (5%). In areas of repeated freeze-thaw cycles, the facing blocks shall be tested in accordance with ASTM C 1262 to demonstrate durability. The facing blocks shall meet the requirements of ASTM C1372 with the exception that the acceptance criteria regarding durability under this testing method shall be achieved such that the weight loss of each of 4 out of the 5 specimens at the conclusion of 150 cycles does not exceed one percent (1%) of its initial weight. Blocks shall also meet the additional requirements of ASTM C140. Facing blocks directly exposed to spray from de-iced pavement shall be sealed after erection with a water resistant coating or be manufactured with a coating or additive to increase freeze-thaw resistance.

9.3.2. Reinforcing Steel
Reinforcing steel shall conform to the requirements of Section 11, "Reinforcing Steel".

9.3.3. Structural Steel
Structural steel shall conform to requirements of Section 13, “Steel Structures”.

1 Classes of concrete are well detailed in Article 10.3 in Section 10, “Concrete Structures”.
9.3.4. Structure Backfill Material

9.3.4.1. General

Unless otherwise specified all structural backfill material shall conform to provisions of Article 4.4, "Backfilling" in Section 4, "Structural Excavation and Backfill" in these Specifications.

All structure backfill material shall consist of material free from organic material or other unsuitable material as determined by the Engineer. Gradation will be determined by AASHTO T27 (ASTM C 136). Grading shall be as follows in Table 9.1, unless otherwise specified.

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 mm</td>
<td>100</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>35-100</td>
</tr>
<tr>
<td>No. 30 (600 μm)</td>
<td>20-100</td>
</tr>
<tr>
<td>No. 200 (75 μm)</td>
<td>0-15</td>
</tr>
</tbody>
</table>

9.3.4.2. Crib and Cellular Walls

Structural backfill material for crib and cellular walls shall be of such character that it will not sift or flow through openings in the wall. For wall heights over 6 meters, the following grading shall be required as mentioned in Table 9.2:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 mm</td>
<td>100</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>25-70</td>
</tr>
<tr>
<td>No. 30 (600 μm)</td>
<td>5-20</td>
</tr>
<tr>
<td>No. 200 (75 μm)</td>
<td>0-5</td>
</tr>
</tbody>
</table>

9.3.4.3. Mechanically Stabilized Earth Walls

Structural backfill material for Mechanically Stabilized Earth walls shall conform to the following grading, internal friction angle and soundness requirements as mentioned in Table 9.3:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 mm</td>
<td>100</td>
</tr>
<tr>
<td>No. 40 (425 μm)</td>
<td>0 - 60</td>
</tr>
<tr>
<td>No. 200 (75 μm)</td>
<td>0 - 15</td>
</tr>
</tbody>
</table>
The material shall exhibit an angle of internal friction of not less than 34°, as determined by the standard direct Shear Test, AASHTO T 236 (ASTM D 3080), on the portion finer than the 2 mm sieve, utilizing a sample of the material compacted to ninety-five percent (95%) of AASHTO T 99, Methods C or D (with oversized correction as outlined in Note 7) at optimum moisture content. No testing is required for backfills where eighty percent (80%) of the sizes are greater than 19 mm.

The materials shall be substantially free of shale or other soft, poor durability particles. The material shall have magnesium sulfate soundness less than thirty percent (30%) after four cycles.

Additionally, the backfill material shall meet the following electrochemical requirements when steel soil reinforcement is to be used:

- pH of 5 to 10.
- Resistivity of not less than 30 ohm meters.
- Chlorides not greater than 100 parts per million.
- Sulfates not greater than 200 parts per million.

9.4. Earthwork

9.4.1. Structural Excavation

Structural excavation for earth retaining systems shall conform to the requirements of Section 4, "Structural Excavation and Backfill", and as provided below.

9.4.2. Foundation Treatment

Foundation Treatment shall conform to the requirements of Article 4.3.3, "Foundation Preparation and Control of Water" unless otherwise specified in the contract documents or included in the approved working drawings. If sub-excavation of foundation material is indicated, the Contractor shall perform the excavation to the limits shown. Material excavated shall be replaced with structural backfill material meeting the requirements for the particular earth retaining system to be constructed unless a different material is specified in the contract documents. The material shall be compacted to a density not less than ninety-five percent (95%) of the maximum density as determined by AASHTO Materials, Part II, Tests, 19th Edition, 1998. T-99, Page 303, Method C, Note 7.

9.4.3. Structural Backfill

Placement of structure backfill material shall conform to the requirements of Article 4.4, "Backfilling" and Article 9.5, "Construction". Material used shall conform to the requirements in Article 9.3.4, "Structure Backfill Material".

9.5. Construction

The construction of earth retaining systems shall conform to the lines and grades indicated in the contract documents or on working drawings or as directed by the Engineer.
9.5.1. Cast-in-place Concrete Walls

9.5.1.1. Architectural Finish

When an architectural finish on the exposed surfaces of the wall is specified in the contract documents, compliance with the following requirements must be considered:

- The Contractor shall submit a sample of the form liner for approval (with working drawings). The contractor shall provide a sample of the architectural finish to evaluate the quality of the liner.
- The Contractor shall use as few joints in the form liner as possible.
- The Contractor shall discard and replace damaged form liner.

9.5.1.2. Retaining Wall Placement

Unless otherwise specified, retaining walls shall be cast with a one percent (1%) batter (leaning toward the backfill side) to compensate for wall deflection caused by the backfill material. Backfill shall not start until all sections within a continuous section of wall have been cast and cured by Section 10, "Concrete Structures" and also Comply with Section 6, "Temporary Structures".

9.5.1.3. Vertical Precast Concrete Wall Elements with Cast-in-Place Concrete Footings

Wall elements shall be adequately supported and braced to prevent vertical or horizontal displacement until footing concrete has been placed, completely cured, and has sufficient strength to support the wall elements. Comply with Section 6, "Temporary Structures".

The exposed face of concrete wall shall receive a Class 1 finish as specified in Section 10, "Concrete Structures," unless a special architectural treatment is specified in the contract documents, or on the approved working drawings.

9.5.2. Sheet Pile And Soldier Pile Walls

This work shall consist of constructing continues walls of timber, steel, or concrete sheet piles, and the constructing of soldier pile walls with horizontal facing elements of timber, steel, or concrete.

9.5.2.1. Sheet Pile Walls

Steel sheet piles shall be of the type and weight indicated in the contract documents. Steel sheet piles shall conform to the requirements of AASHTO M 202M/M202 (ASTM A 328/A328M), AASHTO M 270M/M 270 (ASTM A 709/A709M) Grade 345, or to the specifications for "Piling for use in Marine Environments" in ASTM A 690/A690M. Painting of steel sheet piles for, when required, shall conform to Article 15.2 "Painting Metal Structures". Concrete sheet piles shall conform to the details shown in the contract documents or the approved working drawings. The manufacture and installation shall conform, in general to the requirements for precast concrete bearing piles in Section 7, "Piling and Drilled Shaft Construction". Concrete sheet piles detailed to have a tongue and groove joint on the portion below ground and a double grooved joint on the exposed portion shall, after installation, have the upper grooves cleaned of all sand, mud, or debris, and grouted full. Unless otherwise provided in the contract documents or approved in writing by the Engineer, grout shall be composed of one part cement and two parts sand. The grout shall be deposited through a grout pipe placed within a watertight...
plastic sheath extending the full depth of the grout slot formed by the grooves in two adjacent pilings and which, when filled, completely fills the slot.

Sheet piles shall be driven to the specified penetration or bearing capacity in accordance with the requirements of Section 7, "Piling and Drilled Shaft Construction".

After driving the top of sheet piles shall be neatly cut off to a straight line at the elevation specified in the contract documents, or as directed by the Engineer.

Sheet pile walls shall be braced by wales or other bracing system as shown in the contract documents, or directed by the Engineer.

Reinforced concrete caps, when indicated in the contract documents or on the approved working drawings, shall be constructed in accordance with Section 10, "Concrete Structures".

9.5.2.2. Soldier Pile Walls

Soldier piles shall be either driven piles or piles constructed in a drilled shaft excavation to the specified penetration or bearing capacity indicated in the contract documents.

Driven piles shall be furnished and installed in accordance with the requirements of Section 7, "Pilling and Drilled Shaft Construction". The piles shall be of the type indicated in the contract documents.

Piles constructed in a drilled shaft excavation shall conform to the details shown in the contract documents. Construction of the shaft excavation and placement of concrete or lean concrete backfill shall be in accordance with Section 7, "Piling-Drilled Piles and Shafts". The structural component of the soldier pile placed in the shaft excavation shall be as specified in the contract documents. Reinforced concrete, either cast-in-place or precast, shall conform to the requirements of Section 10, "Concrete Structures". Steel member shall conform to the requirements of Section 13, "Steel Structures". Painting of steel members, if required, shall conform to Section 15, "Painting".

Concrete backfill placed around precast concrete, or steel pile members in the drilled shaft excavation shall be commercially available Portland cement concrete with a cement content not less than 280 kg/m$^3$. Lean concrete backfill shall consist of chemical quality concrete sand, water, and not greater than 56 kg/m$^3$ of Portland cement. The limits for placement of concrete and lean concrete shall be as indicated in the contract documents.

The facing spanning horizontally between soldier piles shall conform to the material and details shown in the contract documents or on the approved working drawings. Precast concrete lagging or facing panels and cast-in-place concrete facing shall conform to the requirements in Section 10, "Concrete Structures". Concrete anchors, welded connections and bolted connections for securing facing elements to the soldier piles shall conform to the details in the contract documents.

The exposed surface of concrete wall facing shall receive a Class 1 finish as specified in Section 10, "Concrete Structures", unless a special architectural treatment is specified in the contract documents, or on the approved working drawings.
9.5.2.3. Anchored Sheet Piles and Soldier Pile Wall

1. General
   The construction of anchored walls shall consist of constructing sheet pile and soldier pile walls anchored with a tie–rod and concrete anchor system or with ground anchors.

   Sheet pile and soldier pile wall construction shall conform to the requirements of Articles 9.5.2.1 "Sheet Piles Walls" and Article 9.5.2.2, "Soldier Pile Walls" respectively.

2. Wales
   Wales consisting of either timber, steel, or concrete shall conform to the details in the contract documents or on the approved working drawings. The alignments of wales shall be such that tie-rods or ground anchors can be installed without bending. Steel wales shall conform to the requirements of Section 13, "Steel Structures". Concrete wales shall conform to the requirements of Section 10, "Concrete Structures".

3. Concrete Anchors System
   Concrete anchors system, consisting of either drilled shafts or reinforced concrete shapes placed within the limits of soil or rock excavation, with or without pile support, shall conform to the details in the contract documents or on the approved working drawings.

   Battered anchor piles shall be driven to the proper batter shown in the contract documents. The tension anchor piles shall be furnished with adequate means of anchorage to the concrete anchor block.

   Drilled shaft concrete anchors shall conform to the details in the contract documents or on approved working drawings, and be constructed in conformance with Section 7, "Drilled Piles and Shafts".

4. Tie–rods
   Tie–rods shall be round steel bars conforming to AASHTO M 270M/M270 (ASTM A 709/A 709M) Grade 250 unless otherwise specified in the contract documents. Corrosion protection shall be provided as specified in the contract documents. Care shall be taken in the handling and backfilling operations to prevent damage to the corrosion protection or bending of the tie-rod itself.

   The connection of the tie–rods to the soldier piles, wales, wall face, and concrete anchor shall conform to the details specified in the contract documents.

5. Ground Anchors
   Ground Anchors shall be constructed in conformance with the requirements of Section 8, "Ground Anchors".

   The connection of the ground anchors to soldier piles, wales, or wall face shall conform to the details in the contract documents or on the approved working drawings.

6. Earthwork
   Earthwork shall conform to the requirements in Article 9.4, "Earthwork".

   Unless otherwise specified in the contract documents, excavation in front of the wall shall not proceed more than 900 mm below a level of tie-rods or ground anchors.
until such tie-rods and anchors or ground anchors are complete and accepted by the Engineer.

Placement of lagging shall closely follow excavation in front of the wall such that loss of ground is minimized and the concrete comply with the requirement of Section 10.

9.5.3. Crib Walls and Cellular Walls

This work shall consist of constructing concrete or steel crib walls and concrete monolithic cell walls complete with backfill material within the cells formed by the members.

9.5.3.1. Foundation

In addition to the requirements of Article 9.4.2, "Foundation Treatment" the foundation or bed course material shall be finished to exact grade and cross slope so that the vertical or battered face alignment will be achieved.

When required, timber mud sills, concrete leveling pads or concrete footings shall conform to the details specified in the contract documents. Timber mud sills shall be firmly and evenly bedded in the foundation material. Concrete for leveling pads or footings shall be placed against the sides of excavation in foundation material.

9.5.3.2. Crib Members

Concrete header and stretcher member shall conform to the requirements of Section 10, "Concrete Structures", for precast concrete members. The dimensions of the members and minimum concrete strength shall be as specified in the contract documents or on the approved working drawings.

Steel crib members consisting of base plates, columns, stretchers and spacers shall be fabricated from sheet steel conforming to AASHTO M218. Thickness of members shall be as specified. Crib members shall be so fabricated that members of same nominal size and thickness shall be fully interchangeable. No drilling, punching, or drifting to correct defects in manufacture shall be permitted. Any members having holes improperly punched shall be replaced. Bolts, nuts, and miscellaneous hardware shall be galvanized in accordance with AASHTO/M232 (ASTM A 153/A 153M).

9.5.3.3. Concrete Monolithic Cell Members

Concrete monolithic cell members consisting of four-sided cells of uniform height and various depths shall be cast in conformance with the requirements set forth for precast members in Section 10, "Concrete Structures". The minimum concrete compressive strength shall be 28 MPa. The exposed cell face shall have a Class 1 finish; face not exposed to view shall have a uniform surface finish free of open pockets of aggregate or surface distortions in excess of 6 mm. The protruding keys and recesses for keys on the tops and bottoms of the side walls of the cells shall be accurately located.

9.5.3.4. Member Placement

Concrete crib members shall be placed in successive tiers at spacing's conforming to the specified details for the particular height of wall being constructed. At the intersection of concrete header and stretchers members, asphalt felt shims or other approved material shall be used to obtain uniform bearing between the members.
Steel columns sections, stretchers and spacers shall conform to the proper length and weight as specified. These members shall be accurately aligned to permit completing the bolted connections without distorting the members. Bolts at the connections shall be torqued to not less than 0.34 kN.m.

Concrete monolithic cell members of the proper sizes shall be successively stacked in conformance with the layout specified in the contract documents or on the approved working drawings. Care shall be exercised in placing the members to prevent damage to the protruding keys. Damaged or ill-fitting keys shall be repaired using a method approved by the Engineer.

9.5.3.5. Backfilling

The cells formed by the wall members shall be backfilled with structural backfill material conforming to the requirements in Article 9.3.4. "Structural Backfill Material". Backfilling shall progress simultaneously with the erection of the members forming the cells. Backfill material shall be so placed and compacted as to not disturb or damage the member. Placement of backfill shall be in uniform layers not exceeding 300 mm in thickness unless otherwise proposed by the Contractor and approved by the Engineer. Compaction shall be to a density of at least ninety-five percent (95%) of the maximum density as determined by AASHTO T 99, Method C. Backfilling behind the wall to the limits of excavation shall conform to the same requirements unless otherwise indicated or approved.

9.5.4. Mechanically Stabilized Earth Walls

The construction of mechanically stabilized earth walls shall consist of constructing a facing system to which steel or polymeric soil reinforcement is connected and the placing of structure backfill material surrounding the soil reinforcement.

9.5.4.1. Facing

Facing consisting of either precast concrete panels, cast-in-place concrete panels, pneumatically-applied mortar, segmental concrete blocks, or welded wire fabric shall conform to the details and materials specified in the contract documents, or on the approved working drawings.

Precast concrete panels shall be cast in conformance with the requirements set forth for precast members in Section 10, "Concrete Structures". The concrete compressive strength shall be that specified in the contract documents or 28 MPa, whichever is greater. The exposed face shall have a Class 1 finish (see Article 10.14.2, "Class 1 Ordinary Surface Finish" in Section 10, "Concrete Structures") or the architectural treatment specified in the contract documents, or on the approved working drawings. The face not exposed to view shall have a uniform surface finish free of open pockets of aggregates or surface distortions in excess of 6mm. Soil reinforcement connection hardware shall be accurately located and secured during concrete placement and shall not contact the panel reinforcing steel. Joint filler, bearing pads, and joint cover material shall be as specified in the contract documents.

Cast-in-place concrete facing shall be constructed in conformance with the requirements in Section 10, "Concrete Structures". Soil reinforcement extending beyond the temporary facing shall be embedded in the facing concrete the minimum dimensions specified in the contract documents or on the approved working drawings.

Welded wire facing, either temporary or permanent, shall be formed by a 90 degree bend of the horizontal soil reinforcement forming the face shall be connected to the
succeeding upper level of soil reinforcement. A separate backing mat and hardware cloth shall be placed immediately behind the vertical portion of soil reinforcement. Its wire size and spacing shall be as specified in the contract documents.

### 9.5.4.2. Soil Reinforcement

All steel soil reinforcement and steel connection hardware shall be galvanized in accordance with AASHTO M 111M/M 111 (ASTM A 123/A 123M).

Steel strip reinforcement shall be hot-rolled to the required shape and dimensions. The steel shall conform to ASTM A 572/A 572M, Grade 450, unless otherwise specified in the contract documents.

Welded wire fabric reinforcement shall be shop fabricated from cold-drawn wire of the size and spacings specified in the contract documents or on the approved working drawings. The wire shall conform to the requirements of AASHTO M 32M/M 32(ASTM A 82); fabricated fabric shall conform to the requirements of AASHTO M 55M/M 55(ASTM A 185).

Polymeric reinforcement shall be of the type and size specified in the contract documents or on the approved working drawings and shall conform to the specified material and manufacturing requirements.

Connection hardware shall conform to the contract documents or the approved working drawings.

The installation of instrumentation for monitoring corrosion shall conform to the requirements specified.

### 9.5.4.3. Construction

When required, a precast reinforced or a cast-in-place concrete leveling pad shall be provided at each panel foundation level. Prior to placing the leveling pads, the foundation material shall conform to the requirements of Article 9.4.2, "Foundation Treatment".

Precast concrete panels, segmental concrete blocks, and welded wire fabric facing shall be placed and supported as necessary so that their final position is vertical or battered as shown in the contract documents or on the approved working drawings within a tolerance acceptable to the Engineer.

Joint filler, bearing pads and joint covering material shall be installed concurrent with face panel placement.

Backfill material conforming to the requirement in Article 9.3.4, "Structure Backfill Material" shall be placed and compacted simultaneously with the placement of facing and soil reinforcement. Placement and compaction and accomplished without distortion or displacement of the facing or soil reinforcement. Sheep foot or grid-type rollers shall not be used for compacting backfill within the limits of the soil reinforcement. At each level of soil reinforcement, the backfill material shall be roughly leveled to an elevation approximately 30 mm above the level of connection at the facing before placing the soil reinforcement. All soil reinforcement shall be uniformly tensioned to remove any slack in the connection or material.

### 9.6. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and for work acceptance, Contractor shall apply quality control for Earth retaining systems work through
carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in this general specifications and other contract documents.

The Ministry shall apply quality assurance and verify the Contractor quality control procedures either through direct supervision or by carrying out neutrally quality assurance procedures using test on representative samples and in adequate numbers to judge about the quality level and accept or reject the executed works according to the principles detailed mentioned bellow in next paragraphs.

9.6.1. Quality Control

The work should be controlled and inspected following the steps of work inspection starting with shop drawing checking and review to assure that it is including all detailed information for construction according to the section 9.2, also, all materials used in construction the work items, should be checked and insure that are fulfill the required specifications of article 9.3 and Table 9.6.

For work acceptance construction should be controlled according to the used retaining system requirements according to the article 9.5.1, 9.5.2, 9.5.3 and 9.5.4 and the stipulated test in Table 9.6.

9.6.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of materials and the constructed works through carrying out or ordering others to carry out under its supervision the tests and asking for the certificates according to the quality requirement which is required to assure the quality of the work according to this specifications and Table 9.6.

9.7. Measurement and Payment

Unless otherwise designated in the contract documents, earth retaining systems shall be measured and paid for by the square meter. The square meter area for payment shall be based on the vertical height and length of each section built, except in the case when alternative earth retaining systems are permitted in the contract documents. When alternative earth retaining systems are permitted, the square meter area for payment will be based on the vertical height and length of each section of the system type designated as the basis of payment whether or not it is actually constructed. The vertical height of each section shall be taken as the difference in elevation on the outer face, from the bottom of the lowermost face element for systems without footings, and from the top of footing for systems with footings, to the top of the wall, excluding any barrier.

The contract price paid per square meter for earth retaining system shall include full compensation for furnishing all labor, materials, tools, equipment, incidental, for doing all the work involved in constructing the earth retaining systems including—but not limited to, earthwork, piles, footings, complete in place as specified in the contract documents, in these specification, and as directed by the Engineer.

Payment will be made under one or more of the items in Table 9.4, the quality control requirements for earth retaining systems are shown in Table 9.5.
Table 9.4: Earth Retaining Systems Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.5.1</td>
<td>Cast-in-place Concrete Walls</td>
<td>Square Meter</td>
</tr>
<tr>
<td>9.5.2.1</td>
<td>Sheet Pile walls</td>
<td>Square Meter</td>
</tr>
<tr>
<td>9.5.2.2</td>
<td>Soldier Pile Walls</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>9.5.3.1</td>
<td>Crib Walls</td>
<td>Square Meter</td>
</tr>
<tr>
<td>9.5.3.2</td>
<td>Cellular Walls</td>
<td>Square Meter</td>
</tr>
<tr>
<td>9.5.4</td>
<td>MSE Walls</td>
<td>Square Meter</td>
</tr>
</tbody>
</table>

Table 9.5: Quality Control Requirements For Earth Retaining Systems

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast-in-place Concrete Walls</td>
<td>Architectural finish</td>
<td>Surveying</td>
<td>In situ</td>
<td>Each</td>
<td>Article 9.5.1.1</td>
</tr>
<tr>
<td></td>
<td>Placement</td>
<td>Surveying</td>
<td>In situ</td>
<td>Each</td>
<td>Article 9.5.1.2</td>
</tr>
<tr>
<td></td>
<td>Vertical pre-cast elements with cast-in-place concrete footings</td>
<td>Surveying</td>
<td>In situ</td>
<td>Each</td>
<td>Article 9.5.1.3</td>
</tr>
<tr>
<td>Sheet pile and soldier pile walls</td>
<td>Sheet pile walls</td>
<td>Surveying</td>
<td>In situ</td>
<td>Each</td>
<td>Article 9.5.2.1 and section 4, &quot;Pilling and Drilled Shaft Construction&quot;.</td>
</tr>
<tr>
<td></td>
<td>Soldier pile walls</td>
<td>Surveying</td>
<td>In situ</td>
<td>Each</td>
<td></td>
</tr>
<tr>
<td>Crib Walls and Cellular Walls</td>
<td>Foundation</td>
<td>Surveying</td>
<td>In situ</td>
<td>Each</td>
<td>Article 9.5.3.1 and article 9.4.2, &quot;Foundation Treatment&quot;.</td>
</tr>
<tr>
<td></td>
<td>Crib members</td>
<td>Surveying</td>
<td>In situ</td>
<td>Each</td>
<td>Article 9.5.3.2 and Section 10, &quot;Concrete Structures&quot;.</td>
</tr>
<tr>
<td></td>
<td>Concrete monolithic cell members</td>
<td>Surveying</td>
<td>In situ</td>
<td>Each</td>
<td>Article 9.5.3.3 and Section 10, &quot;Concrete Structures&quot;.</td>
</tr>
<tr>
<td></td>
<td>Member placement</td>
<td>Surveying</td>
<td>In situ</td>
<td>Each</td>
<td>Article 9.5.3.4</td>
</tr>
<tr>
<td></td>
<td>Backfilling</td>
<td>Surveying</td>
<td>In situ</td>
<td>As directed by the engineer</td>
<td>Article 9.5.3.5 and article 9.3.4, &quot;Structural Backfill Material&quot;.</td>
</tr>
</tbody>
</table>
Table 9.6: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>when meet the requirement of th test.</td>
<td></td>
<td>ASTMC 1262</td>
<td>Standard Test Method for Evaluating the Freeze-Thaw Durability of Dry-Cast Segmental Retaining Wall Units and Related Concrete Units</td>
</tr>
<tr>
<td>when meet the requirement of the test with the exception that the acceptance criteria regarding durability under this testing method shall be achieved such that the weight loss of each of 4 out of the 5 specimens at the conclusion of 150 cycles does not exceed one percent (1%) of its initial weight</td>
<td></td>
<td>ASTMC 1372</td>
<td>Standard Specification for Dry-Cast Segmental Retaining Wall Units</td>
</tr>
<tr>
<td>when meet the requirement of th test.</td>
<td></td>
<td>ASTMC 140</td>
<td>Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units</td>
</tr>
<tr>
<td>an angle of internal friction of not less than 34°</td>
<td>AASHTOT 236</td>
<td>(ASTMD 3080)</td>
<td>Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions</td>
</tr>
<tr>
<td>when meet the requirement of th test, and no testing is required for backfills where eighty percent (80%) of the sizes are greater than 19 mm.</td>
<td>AASHTOT 99</td>
<td>(ASTM C966 - 98(2008))</td>
<td>Standard Guide for Installing Asbestos-Cement Nonpressure Pipe</td>
</tr>
<tr>
<td>As specified.</td>
<td></td>
<td>ASTMA 690/A690M</td>
<td>Standard Specification for High-Strength Low-Alloy Nickel, Copper, Phosphorus Steel H-Piles and Sheet Piling with Atmospheric Corrosion Resistance for Use in Marine Environments</td>
</tr>
<tr>
<td>As specified.</td>
<td>AASHTOM 202M/M202</td>
<td>(ASTMA 328/A328M)</td>
<td>Standard Specification for Steel Sheet Piling</td>
</tr>
<tr>
<td>As specified.</td>
<td>AASHTOM 270M/M 270</td>
<td>(ASTMA 709/A709M)</td>
<td>Standard Specification for Structural Steel for Bridges</td>
</tr>
<tr>
<td>As specified.</td>
<td>AASHTOM M218</td>
<td></td>
<td>Standard Specification for Steel Sheet, Zinc-Coated</td>
</tr>
<tr>
<td>As specified.</td>
<td>AASHTOM 232</td>
<td>(ASTMA 153/A 153M)</td>
<td>Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware</td>
</tr>
<tr>
<td>As specified.</td>
<td>AASHTOM 111M/M 111</td>
<td>(ASTMA 123/A 123M)</td>
<td>Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products</td>
</tr>
<tr>
<td>As specified.</td>
<td>ASTMA 572/A 572M</td>
<td></td>
<td>Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel</td>
</tr>
<tr>
<td>As specified.</td>
<td>AASHTOM M 32M/M 32</td>
<td>(ASTMA 82)</td>
<td>Standard Specification for Steel Wire, Plain, for Concrete Reinforcement</td>
</tr>
<tr>
<td>As specified.</td>
<td>AASHTOM M 55M/M 55</td>
<td>(ASTM A 185)</td>
<td>Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete</td>
</tr>
</tbody>
</table>
9.8. References

OKLAHOMA. “Oklahoma Department of Transportation Standard Specifications for Highway Construction”-2002- Sec. 510

AASHTO: "Bridges Construction Specifications"- 2004. Sec. 7

MOMRA: Kingdom of Saudi Arabia Ministry of Municipal & Rural Affairs Deputy Ministry for Technical Affairs –"Bridges Design Specifications" (MA-100-D-V1/2 & V2/2)-2011.
SECTION 10. CONCRETE STRUCTURES

10.1. Notation

\[ f'_c \] = Specified Compressive Strength Of Concrete, Mpa.
\[ f'_{cr} \] = Required average compressive strength of concrete used as the basis for selection of concrete proportions, MPa.
\[ s \] = Standard deviation, MPa.

10.2. General

10.2.1. Description

This work shall consist of furnishing, placing, finishing, and curing concrete in bridges, culverts, and miscellaneous structures in accordance with these specifications and conforming to the lines, grades and dimensions shown on the contract documents. The work includes elements of structures constructed by cast-in-place and precast methods using either plain (unreinforced), reinforced, or prestressed concrete or any combination thereof.

10.2.2. Related Work

Other works involved in the construction of concrete structures shall be as specified in the applicable sections of these specifications, especially Section 6, "Temporary Structures", Section 11, "Reinforcing Steel" and Section 12, "Prestressing".

10.2.3. Construction Methods

Whenever the contract documents permit the Contractor to select the method or equipment to be used for any operation, it shall be the Contractor's responsibility to employ methods and equipment which will produce satisfactory work under the conditions encountered such that no damage is imparted on completed or partially completed work.

Falsework and forms shall conform to the requirements of Section 6, "Temporary Structures".

Generally, all concrete shall be fully supported until the required strength and age has been reached. However, the slip form method may be permitted for the construction of pier shafts and railing providing the Contractor's plan assures that:

- The results will be equal in all respect to those obtained by the use of fixed forms.
- Adequate arrangements will be provided for curing, finishing, and protecting the concrete.

10.3. Classes Of Concrete

10.3.1. General

The class of concrete to be used in each part of the structure shall be as specified or shown on the contract documents. If not shown or specified, the Engineer will designate the class of concrete to be used.
10.3.2. Normal-Weight Concrete

Classes of normal weight (density) concrete are provided for in these specifications as listed in Table 10.1 except that for concrete on or over saltwater or exposed to deicing chemical, the maximum water/cement ratio shall be 0.45.

Coarse aggregate for class B shall be furnished into separate sizes as shown in Table 10.1.

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Minimum Cement Content (Kg/m³)</th>
<th>Maximum water/Cementations Material Ratio</th>
<th>Size of Coarse Aggregate Per AASHTO M 43 (ASTM D 448) (Nominal Size)</th>
<th>Specified Compressive Strength (MPa at 28 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A &amp; B</td>
<td>363</td>
<td>0.49</td>
<td>2 to No.4</td>
<td>28</td>
</tr>
<tr>
<td>C</td>
<td>390</td>
<td>0.49</td>
<td>12.5 mm to No.4</td>
<td>28</td>
</tr>
<tr>
<td>P</td>
<td>335</td>
<td>0.49</td>
<td>25 mm to No.4 or 19.0 mm to No.4</td>
<td>≤ 41 at b</td>
</tr>
<tr>
<td>S</td>
<td>390</td>
<td>0.58</td>
<td>25 mm to No.4</td>
<td>---</td>
</tr>
<tr>
<td>P (HPC)</td>
<td>---</td>
<td>0.40</td>
<td>≤ 19.0 mm</td>
<td>&gt; 41 at b</td>
</tr>
<tr>
<td>A (HPC)</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>≤ 41 at b</td>
</tr>
</tbody>
</table>

Notes:
a: As noted in AASHTO M43 (ASTM D 448), Table 1-Standard Size of Processed Aggregate.
b: As specified in the contract documents.
c: Minimum cementitious material content and coarse aggregate size to be selected to meet other performance criteria specified in the contract.
e: HPC = High Performance Concrete.

10.3.3. Lightweight Concrete

Lightweight (low-density) concrete shall conform to the requirements specified in the contract documents. When the contract documents require the use of natural sand for a portion or all of the fine aggregate, the natural sand shall conform to AASHTO M6.

10.4. Materials

The five major constituent materials of concrete produced today are cement, aggregates, mineral admixtures, chemical admixtures and water.

10.4.1. Cements

Cement for use in bridge construction generally conforms to one of the following specifications:

- AASHTO M85 (ASTM C 150) for Portland cement.
- AASHTO M240 (ASTM C 595) or ASTM C 1157 for blended hydraulic cement.
- ASTM C 845 for expansive hydraulic cement.

The types of Portland cement are as follows:

- Type I Normal
- Type II Moderate sulphate resistant
- Type III High early strength
- Type IV Low heat of hydration
- Type V High sulphate resistance

10.4.2. Aggregates

10.4.2.1. Fine aggregate

Fine aggregate for concrete shall conform to the requirements of AASHTO M6.

10.4.2.2. Coarse aggregate

Coarse aggregate for concrete shall conform to the requirements of AASHTO M80.

Nominal maximum size of coarse aggregate shall be not larger than:

a) 1/5 the narrowest dimension between sides of forms, nor
b) 1/3 the depth of slabs, nor
c) 3/4 the minimum clear spacing between individual reinforcing bars or wires, bundles of bars, individual tendons, bundled tendons, or ducts.

These limitations shall not apply if, in the judgment of the engineer, workability and methods of consolidation are such that concrete can be placed without honeycombs or voids.

10.4.2.3. Blended Aggregates

Where suitable lightweight aggregates are available, a common practice is to blend lightweight with normal weight aggregates to achieve a desired concrete unit weight. This is done to control beam (or other product) weights to satisfy shipping limitations, jobsite conditions such as crane size, reach limits, plant, or erection equipment capacities.

Blends of fine and coarse aggregates shall conform to the requirements of AASHTO M XXI.

10.4.2.4. Lightweight aggregate

Lightweight aggregate for concrete shall conform to the requirements of AASHTO M 195 (ASTM C 330).

10.4.2.5. Exception

Aggregates that have been shown by special test or actual service to produce concrete of adequate strength and durability and approved by the Ministry.

10.4.3. Admixtures

10.4.3.1. Mineral Admixtures

Mineral admixtures are powdered or pulverized materials added to concrete to improve or change the properties of hardened portland cement concrete. Mineral admixtures are used in concrete to increase early strength development or to reduce the heat of hydration. They may also be used to improve the resistance of concrete to reactive aggregates and to replace cement. They have also been used in high strength concrete to produce higher strengths at later ages. The use of mineral admixtures may affect the workability and finishing characteristics of fresh concrete.
1. Pozzolans

AASHTO M295 (ASTM C 618) lists three classes of mineral admixtures as follows:

- Class C Fly ash
- Class F Fly ash
- Class N Raw or calcined natural pozzolans

High-Reactive Metakaolin (HRM) is a manufactured white powder that meets the requirements of a Class N pozzolan. HRM has a particle size significantly smaller than that of cement particles, but not as fine as silica fume. Fly ash is a finely divided residue that results from the combustion of pulverized coal in power generation plants. Class F fly ash has pozzolanic properties; Class C has some cementitious properties in addition to pozzolanic properties. Some fly ashes meet both Class F and Class C classifications.

Selection of these materials will depend on their local availability and their effect on concrete properties.

Fly ash as produced by plants that utilize the limestone injection process or use compounds of sodium, ammonium or sulfur, such as soda ash, to control stack emissions shall not be used in concrete.

2. Silica Fume

Silica fume meeting the requirements of AASHTO M307 (ASTM C 1240) may also be used as a mineral admixture in concrete. Silica fume is a very fine pozzolanic material produced as a by-product in electric arc furnaces used for the production of elemental silicon or ferro-silicon alloys. Silica fume is also known as condensed silica fume and microsilica.

The use of silica fume can improve the early age strength development of concrete and is particularly beneficial in achieving high release strengths in high strength concrete beams. The use of silica fume in concrete generally results in concrete that has low permeability. The use of silica fume increases the water demand in concrete. Consequently, it is generally used in combination with a water-reducing admixture or a high range water-reducing admixture. Concrete containing silica fume has significantly less bleeding and the potential for plastic shrinkage is increased. Therefore, early moisture loss should be prevented under conditions which promote rapid surface drying such as low humidity and high temperatures.

3. Slag

Ground granulated blast-furnace slag shall meet the requirements of AASHTO M 302 (ASTM C 989).

A Certificate of Compliance, based on test results and signed by the producer of the mineral admixture certifying that the material conforms to the above specifications, shall be furnished for each shipment used in the work.

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1 Pozzolans (fly ash, silica fume) and slag are used in the production of Class P(HPC) and Class A(HPC) concretes to extend their service life.
Where special materials other than those identified above are included in a concrete mix design, the properties of those materials shall be determined by methods specified in the contract documents.

10.4.3.2. Chemical Admixtures

Chemical admixtures are used in precast, prestressed concrete to provide air entrainment, reduce water content, improve workability, retard setting times and accelerate strength development. Chemical admixtures, except air-entraining admixtures, should conform to the requirements of AASHTO M194. Air-entraining admixtures shall conform to the requirements of AASHTO M154 (ASTM C 260).

Air-entraining admixtures are used in concrete primarily to increase the resistance of the concrete to freeze-thaw damage when exposed to water and deicing chemicals. They may also be used to increase workability and facilitate handling and finishing. Air-entraining admixtures should conform to AASHTO M154. The air content of fresh concrete is generally determined using the pressure method (AASHTO T152) or the volumetric method (AASHTO T196). The pressure method should not be used with lightweight concrete. A pocket-size air indicator (AASHTO T199) can be used for quick checks but is not a substitute for the other more accurate methods.

This specification lists the following types of admixtures:
- Type A Water-reducing
- Type B Retarding
- Type C Accelerating
- Type D Water-reducing and retarding
- Type E Water-reducing and accelerating
- Type F Water-reducing, high range
- Type G Water-reducing, high range and retarding

Air-entraining and chemical admixtures shall be incorporated into the concrete mix in a water solution. The water so included shall be considered to be a portion of the allowed mixing water.

The use of calcium chloride in concrete promotes corrosion of metals due to the presence of chloride ions. Consequently, admixtures containing chloride ion (\(c^+\)) in excess of one percent by weight of the admixture shall not be used in reinforced concrete. Admixtures in excess of 0.1 percent shall not be used in prestressed concrete.

If more than one admixture is used, the admixtures shall be compatible with each other and shall be incorporated into the concrete mix in correct sequence so that the desired effects of all admixtures are obtained. If such combination of admixtures has not been used before by the constructor and the manufacturer does not give any guidance, short term and long term properties of concrete with the untested combination shall be examined by an expert to assess any vulnerabilities of the concrete to accelerated degradation as a result of such new combination.

A Certificate of Compliance (COC) signed by the manufacturer of the admixture shall be furnished to the Engineer for each shipment of admixture used in the work. The Certificate of Compliance shall be based upon laboratory test results from an approved testing facility and shall certify that the admixture meets the above specifications.
10.4.4. Water

Water used in mixing or curing concrete shall be clean and free from harmful amounts of oils, acids, alkalis, salts, organic materials, or other substances deleterious to concrete, reinforcement, or any imbedded components in the concrete.

Mixing water for prestressed concrete, reinforced concrete or for concrete that will contain aluminum embedments, including that portion of mixing water contributed in the form of free moisture on aggregates, shall not contain deleterious amounts of chloride ion.

Non-potable water shall not be used in concrete unless the following are satisfied:

- The following limits of water for concrete (mixing or curing) shall not be exceeded: alkali carbonate and bicarbonate 1000 ppm, chlorides 1000 ppm, sulfates 3000 ppm, alkalis 600 ppm, and pH (minimum).
- Mortar test cubes made with non-potable mixing water containing more than 2000 ppm of total dissolved solids shall have 7-day and 28-day strengths equal to at least 90 percent of strengths of similar specimens made with potable water. Strength test comparison shall be made on mortar, identical except for the mixing water, prepared and tested in accordance with ASTM C 109.

10.5. Proportioning of Concrete

Proportions of constituent materials for concrete shall be established to provide:

a) Workability and consistency to permit concrete to be easily worked into forms and around reinforcement under conditions of placement to be employed, without segregation or excessive bleeding;

b) Resistance to special exposures;

c) Conformance with strength test requirements.

d) Acceptable color and texture (i.e. aesthetics).

10.5.1. Mixing

10.5.1.1. Responsibility and Criteria

The Contractor shall design and be responsible for the performance of all concrete mixes used in structures. The mix proportions selected shall produce concrete that is sufficiently workable and finishable for all uses intended and shall conform to the requirements in Table 10.1 and all other requirements of this Section.

For normal weight concrete the absolute volume method, such as described in ACI 211.1, shall be used in selecting mix proportions. For structural lightweight concrete, the mix proportions shall be selected on the basis of trial mixes with the cement factor rather than the water/cement ratio being determined by the specified strength using methods such as those described in ACI 211.2.

Ready-mixed concrete shall be mixed and delivered in accordance with requirements of "Specification for Ready-Mixed Concrete" (ASTM C 94) or "Specification for Concrete Made by Volumetric Batching and Continuous Mixing" (ASTM C 685).

Job-mixed concrete shall be mixed in accordance with the following:

- Mixing shall be done in a batch mixer of approved type;
- Mixer shall be rotated at a speed recommended by the manufacturer;
Mixing shall be continued for at least 1.5 minutes and not more than 5 minutes after all materials are in the drum, unless a shorter time is shown to be satisfactory by the mixing uniformity tests of "Specification for Ready-Mixed Concrete" (ASTM C 94);

Materials handling, batching, and mixing shall conform to applicable provisions of "Specification for Ready-Mixed Concrete" (ASTM C 94);

A detailed record shall be kept to identify:
1) Number of batches produced;
2) Proportions of materials used;
3) Approximate location of final deposit in structure;
4) Time and date of mixing and placing.

10.5.1.2. Trial Batch Test

1. Standard Deviation

Where a concrete production facility has test records, a standard deviation shall be established. Test records from which a standard deviation is calculated:

a) Shall represent materials, quality control procedures, and conditions similar to those expected and changes in materials and proportions within the test records shall not have been more restricted than those for proposed work;

b) Shall represent concrete produced to meet a specified strength or strengths $f'_c$ within 7 MPa of that specified for proposed work;

c) Shall consist of at least 30 consecutive tests or two groups of consecutive tests totaling at least 30 tests as defined in Article 10.6.7.1, "Frequency of Testing" (spanning over a period of not less than 45 days), except as provided in the next paragraph.

Where a concrete production facility does not have test records meeting requirements of this Article, but does have a record based on 15 to 29 consecutive tests, a standard deviation shall be established as the product of the calculated standard deviation and modification factor of Table 10.2. To be acceptable, test record shall meet requirements (a) and (b) of this Article, and represent only a single record of consecutive tests that span a period of not less than 45 calendar days.

<table>
<thead>
<tr>
<th>No. of tests*</th>
<th>Modification factor for standard deviation †</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 15</td>
<td>Use Table 10.4</td>
</tr>
<tr>
<td>15</td>
<td>1.16</td>
</tr>
<tr>
<td>20</td>
<td>1.08</td>
</tr>
<tr>
<td>25</td>
<td>1.03</td>
</tr>
<tr>
<td>30 or more</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*Interpolate for intermediate numbers of tests.
†Modified standard deviation to be used to determine required average strength $f'_c$, from Article 10.5.1.2.2, “Required Average Strength”.

Table 10.2: Modification factor for Standard Deviation when less than 30 tests are available
2. Required Average Strength
Required average compressive strength \( f'_{cr} \) used as the basis for selection of concrete proportions shall be determined from Table 10.3 using the standard deviation calculated in accordance with Article 10.5.1.1, “Standard Deviation”.

Table 10.3: Required Average Compressive Strength When Data are Available to Establish a Standard Deviation

<table>
<thead>
<tr>
<th>Specified compressive strength, ( f'_{c} ), MPa</th>
<th>Required average compressive strength, ( f'_{cr} ), MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f'_{c} \leq 35 )</td>
<td>Use the larger value computed from the following equations: ( f'<em>{cr} = f'</em>{c} + 1.34 \sigma ) ( f'<em>{cr} = f'</em>{c} + 2.33 \sigma - 3.45 )</td>
</tr>
<tr>
<td>Over 35</td>
<td>Use the larger value computed from the following equations: ( f'<em>{cr} = f'</em>{c} + 1.34 \sigma ) ( f'<em>{cr} = 0.9 f'</em>{c} + 2.33 \sigma )</td>
</tr>
</tbody>
</table>

When a concrete production facility does not have field strength test records for calculation of standard deviation meeting requirements of Article 10.5.1.2.1, “Standard Deviation” required average strength \( f'_{cr} \) shall be determined from Table 10.4 and documentation of average strength shall be in accordance with requirements of Article 10.5.1.3, “Documentation of Average Strength”.

Table 10.4: Required average compressive strength when data are not available to establish a Standard Deviation

<table>
<thead>
<tr>
<th>Specified compressive strength, ( f'_{c} ), MPa</th>
<th>Required average compressive strength, ( f'_{cr} ), MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 to 35</td>
<td>( f'_{c} + 8.5 )</td>
</tr>
<tr>
<td>Over 35</td>
<td>( 1.10 f'_{c} + 5.0 )</td>
</tr>
</tbody>
</table>

10.5.1.3. Documentation of Average Strength
Documentation that proposed concrete proportions will produce an average compressive strength equal to or greater than required average compressive strength (see Article 10.5.1.2.2, “Required Average Strength”) shall consist of a field strength test record, several strength test records, or trial mixtures.

When test records are used to demonstrate that proposed concrete proportions will produce the required average strength \( f'_{cr} \) (see Article 10.5.1.2.2, “Required Average
Strength”), such records shall represent materials and conditions similar to those expected. Changes in materials, conditions, and proportions within the test records shall not have been more restricted than those for proposed work. For the purpose of documenting average strength potential, test records consisting of less than 30 but not less than 10 consecutive tests are acceptable provided that test records encompass a period of time not less than 45 days. Required concrete proportions shall be permitted to be established by interpolation between the strengths and proportions of two or more test records, each of which meets other requirements of this section.

When an acceptable record of field test results is not available, concrete proportions established from trial mixtures meeting the following restrictions shall be permitted:

a) Combination of materials shall be those for proposed work;

b) Trial mixtures having proportions and consistencies required for proposed work shall be made using at least three different water cementitious materials ratios or cementitious materials contents that will produce a range of strengths encompassing the required average strength $f'_{cr}$;

c) Trial mixtures shall be designed to produce a slump within ±20 mm of maximum permitted, and for air-entrained concrete, within ±0.5 percent of maximum allowable air content;

d) For each water-cementitious materials ratio or cementitious materials content, at least three test cylinders for each test age shall be made and cured in accordance with "Method of Making and Curing Concrete Test Specimens in the Laboratory" (ASTM C 192). Cylinders shall be tested at 28 days or at test age designated for determination of $f'_{cr}$;

e) From results of cylinder tests a curve shall be plotted showing the relationship between water-cementitious materials ratio or cementitious materials content and compressive strength at designated test age;

f) Maximum water-cementitious materials ratio or minimum cementitious materials content for concrete to be used in proposed work shall be that shown by the curve to produce the average strength required by Article 10.5.1.2.2, "Required Average Strength" unless a lower water-cementitious materials ratio or higher strength is required by Article 10.7, "Protection of Concrete from Environmental conditions". If data required by Table 10.4 are not available, concrete proportions shall be based upon other experience or information, if approved by an expert. The required average compressive strength $f'_{cr}$ of concrete produced with materials similar to those proposed for use shall be at least 8.5 MPa greater than the specified compressive strength $f'_{cr}$. This alternative shall not be used for specified compressive strengths greater than 35 MPa.

Concrete proportioned by this section shall conform to the durability requirements of Article 10.7, "Protection of Concrete from Environmental conditions" and to compressive strength test criteria of Article 10.6.7, "Evaluation and Acceptance of Concrete".

1. Average Strength Reduction

As data become available during construction, it shall be permitted to reduce the amount by which $f'_{cr}$ must exceed the specified value of $f'_{cr}$, provided:
a) Thirty or more test results are available and average of test results exceeds that required by Article 10.5.1.2.2, “Required Average Strength” using a standard deviation calculated in accordance with Article 10.5.1.2.1 (first paragraph); or
b) Fifteen to 29 test results are available and average of test results exceeds that required by Article 10.5.1.2.2, “Required Average Strength” using a standard deviation calculated in accordance with Article 10.5.1.2.1 (second paragraph); and
c) Special exposure requirements of Article 10.7, "Protection of Concrete from Environmental conditions" are met.

10.5.2. Water Content

For calculating the water/cement ratio of the mix, the weight of the water shall be that of the total free water in the mix which includes the mixing water, the water in any admixture solutions and any water in the aggregates in excess of that needed to reach a saturated-surface-dry condition.

The amount of water used shall not exceed the limits listed in Table 10.1 for W/C ratio and shall be further reduced as necessary to produce concrete of the consistencies listed in Table 10.5 at the time of placement.

<table>
<thead>
<tr>
<th>Type of Work</th>
<th>Nominal Slump millimeters</th>
<th>Maximum Slump millimeters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formed Elements:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sections Over 300 mm Thick</td>
<td>25-75</td>
<td>125</td>
</tr>
<tr>
<td>Sections 300 mm thick or Less</td>
<td>25-100</td>
<td>125</td>
</tr>
<tr>
<td>Cast-in-place Piles and Drilled Shafts not Vibrated</td>
<td>125-200</td>
<td>225</td>
</tr>
<tr>
<td>Concrete Placed Under Water</td>
<td>125-200</td>
<td>225</td>
</tr>
<tr>
<td>Filling for Rip-rap</td>
<td>75-175</td>
<td>200</td>
</tr>
</tbody>
</table>

When Type F or G high range water reducing admixtures are used, Table 10.5 slump limits may be exceeded as permitted by the Engineer.

When the consistency of the concrete is found to exceed the nominal slump, the mixture of subsequent batches shall be adjusted to reduce the slump to a value within the nominal range. Batches of concrete with a slump exceeding the maximum specified shall not be used in the work.

If concrete of adequate workability cannot be obtained by the use of the minimum cement content allowed, the cement and water content shall be increased without exceeding the specified water/cement ratio, or an approved admixture shall be used.

10.5.3. Cement Content

The minimum cement content shall be as listed in Table 10.1 or otherwise specified in the contract documents. For Class P (HPC), the total cementitious materials content shall not exceed 600 kg/m$^3$ of concrete. For other classes of concrete, maximum cement or cement plus mineral admixture content shall not exceed 475 kg/m$^3$ of concrete. The actual cement content used shall be within these limits and shall be sufficient to produce concrete of the required strength, consistency, and performance.
10.5.4. Admixtures

Concrete admixtures shall be added to the concrete mix at the time of batching the concrete or in accordance with the manufacturer’s written procedure and as approved by the Engineer. A copy of the manufacturer’s written procedure shall be furnished to the Engineer prior to use of any admixture. Any deviations from the manufacturer’s written procedures shall be submitted to the Engineer for approval. Admixtures shall not be added to the concrete with the modified procedure until the Engineer has approved them in writing.

When the Contractor is proposing to use admixtures from different admixture manufacturers, the Contractor shall provide evidence to the Engineer that the admixture will be compatible and does not adversely affect the air void system of the hardened concrete. Test results complying with ASTM C 457 shall be provided as an evidence to satisfy this requirement.

10.5.4.1. Mineral Admixtures

Mineral admixtures shall be used in the amounts specified in the contract documents. For all classes of concrete except Classes P (HPC) and A (HPC), when Types I, II, IV, or V AASHTO M 85 (ASTM C 150) cements are used and mineral admixtures are neither specified in the contract documents nor prohibited, the Contractor will be permitted to replace:

- Up to twenty-five percent (25%) of the required portland cement with fly ash or other pozzolan conforming to AASHTO M 295 (ASTM C 618),
- Up to fifty percent (50%) of the required portland cement with slag conforming to AASHTO M 302 (ASTM C 989), or
- Up to ten percent (10%) of the required portland cement with silica fume conforming to AASHTO M 307 (ASTM C 1240).

When any combination of fly ash, slag, and silica fume are used, the Contractor will be permitted to replace up to 50 percent of the required portland cement. However, no more than twenty-five percent (25%) shall be fly ash and no more than ten percent (10%) shall be silica fume. The weight of the mineral admixture used shall be equal to or greater than the weight of the portland cement replaced. In calculating the water-cementitious materials ratio of the mix, the weight of the cementitious materials shall be considered to be the sum of the weight of the portland cement and the mineral admixtures.

For Class P(HPC) and Class A(HPC) concrete, mineral admixtures (pozzolans or slag) shall be permitted to be used as cementitious materials with portland cement in blended cements or as a separate addition at the mixer. The amount of mineral admixture shall be determined by trial batches. The water cementitious materials ratio shall be the ratio of the weight of water to the total cementitious materials, including the mineral admixtures. The properties of the freshly mixed and hardened concrete shall comply with specified values.

10.5.4.2. Chemical Admixtures

Chemical admixtures may be used if prior approval is obtained from the Engineer, except that calcium chloride will not be permitted.

Methods and equipment for measuring and adding additives shall be approved by the Engineer. Equipment which will not accurately dispense the correct amount of additive in an acceptable manner will not be approved.
No separate payment for additives used in the mix will be made.

10.6. Manufacture of Concrete

The production of ready-mixed concrete and concrete produced by stationary mixers shall conform to the requirements of AASHTO M157 and the requirements of this Article.

10.6.1. Storage of Cement

The Contractor shall provide suitable means for storing and protecting cement against dampness. Cement which for any reason has become partially set or which contains lumps of caked cement will be rejected. Cement held in storage for a period of over 3 months if bagged or 6 months if bulk, or cement which for any reason the Engineer may suspect of being damaged, shall be subject to a retest before being used in the work.

Copies of cement records shall be furnished to the Engineer, showing, in such detail, and as may reasonably require, the quantity used during the day or run in each part of the work.

10.6.2. Storage of Aggregates

The handling and storage of concrete aggregates shall be such as to prevent segregation or contamination with foreign materials. The methods used shall provide for adequate drainage so that the moisture content of the aggregates is uniform at the time of batching. Different sizes of aggregate shall be stored in separate stock piles sufficiently removed from each other to prevent the material at the edges of the piles from becoming intermixed.

When Specified in Table 10.1 or in the special provisions, the coarse aggregate shall be separated into two or more sizes in order to secure greater uniformity of the concrete mixture

10.6.3. Measurements of Materials

Materials shall be measured by weighing, except as otherwise specified or where other methods are specifically authorized. The apparatus provided for weighing the aggregates and cement shall be suitably designed, calibrated, and constructed for this purpose. Each size of aggregate and the cement shall be weighed separately. The accuracy of all weighing devices shall be such that successive quantities can be measured to within one percent (1%) of the desired amount. Cement in standard packages (sack) need not be weighed, but bulk cement shall be weighed. The mixing water shall be measured by volume or by weight. The accuracy of measuring the water shall be within a range of error of not over one percent (1%). All measuring devices shall be subject to approval and shall be tested, at the Contractor's expense, when deemed necessary by the Engineer.

When volumetric measurements are authorized for projects, the weight proportions shall be converted to equivalent volumetric proportions. In such cases, suitable allowance shall be made for variations in the moisture condition of the aggregates, including the bulking effect in the fine aggregate.

When sacked cement is used, the quantities of aggregates for each batch shall be exactly sufficient for one or more full sacks of cement and no batch requiring fractional sacks of cement will be permitted.
**10.6.4. Batching and Mixing of Concrete**

**10.6.4.1. Batching**

The size of the batch shall not exceed the capacity of the mixer as guaranteed by the manufacturer.

The measured materials shall be batched and charged into the mixer by means that will prevent loss of any materials due to effects of wind or other causes.

**10.6.4.2. Mixing**

The concrete shall be mixed only in the quantity required for immediate use. Mixing shall be sufficient to thoroughly intermingle all mix ingredients into a uniform mixture. Concrete that has developed an initial set shall not be used. Retempering concrete by adding water will not be permitted.

For other than transit mixed concrete, the first batch of concrete materials placed in the mixer shall contain a sufficient excess of cement, sand, and water to coat the inside of the drum without reducing the required mortar content of the mix.

When mixer performance tests, as described in AASHTO M 157, are not made, the required mixing time for stationary mixers shall be not less than 90 seconds nor more than 5 minutes. The minimum drum revolutions for transit mixers at the mixing speed recommended by the manufacturer shall not be less than 70 and not less than that recommended by the manufacturer.

The timing device on stationary mixers shall be equipped with a bell or other suitable warning device adjusted to give a clearly audible signal each time the lock is released. In case of failure of the timing device, the Contractor will be permitted to operate while it is being repaired, provided he furnishes an approved timepiece equipped with minute and second hands. If the timing device is not placed in good working order within 24 hours, further use of the mixer will be prohibited until repairs are made.

For small quantities of concrete needed in emergencies or for small non-critical elements of the work, concrete may be mixed in situ using methods approved by the Engineer.

Between uses, any mortar coating inside of mixing equipment which sets or dries shall be cleaned from the mixer before use is resumed.

**10.6.5. Delivery**

The company supplying concrete shall have sufficient plant capacity and transporting apparatus to ensure continuous delivery at the rate required. The rate of delivery of concrete during concreting operations shall be such as to provide for the proper handling, placing, and finishing of the concrete. The rate shall be such that the interval between batches shall not exceed 20 minutes and shall be sufficient to prevent joints within a monolithic pour caused by placing fresh concrete against concrete in which initial set has occurred. The methods of delivering and handling the concrete shall be such as will facilitate placing with the minimum of rehandling and without damage to the structure or the concrete.

**10.6.6. Sampling and Testing**

Compliance with the requirements indicated in this Section shall be determined in accordance with the following standard methods of AASHTO or ASTM:
- Sampling Fresh Concrete, AASHTO T 141 (ASTM C 172)
- Weight per Cubic Meter, Yield, and Air Content (Gravimetric) of Concrete, AASHTO T 121 (ASTM C 138C 138M)
- Sieve Analysis of Fine and Coarse Aggregate, AASHTO T 27 (ASTM C 136)
- Slump of Portland Cement Concrete, AASHTO T 119, (ASTM C 143C 143M)
- Air Content of Freshly Mixed Concrete by the Pressure Method, AASHTO T 152 (ASTM C 231)
- Specific Gravity and Absorption of Fine Aggregate, AASHTO T 84 (ASTM C 128)
- Specific Gravity and Absorption of Coarse Aggregate, AASHTO T 85 (ASTM C 127)
- Determining Density of Structural Lightweight (Low-Density) Concrete, ASTM C 567
- Making and Curing Concrete Test Specimens in the Laboratory, AASHTO T 126 (ASTM C 192/C 192M)
- Making and Curing Concrete Test Specimens in the Field, AASHTO T 23 (ASTM C 31/C 31M)
- Compressive Strength of Cylindrical Concrete Specimens, AASHTO T 22 (ASTM C 39/C 39M)

10.6.7. Evaluation and Acceptance of Concrete

Concrete shall be tested in accordance with the requirements of Article 10.6.7.1, "Frequency of testing" through 10.6.7.4, "Investigation of low-strength test results". Qualified field testing technicians shall perform tests on fresh concrete at the job site, prepare specimens required for curing under field conditions, prepare specimens required for testing in the laboratory, and record the temperature of the fresh concrete when preparing specimens for strength tests. Qualified and disinterested laboratory technicians shall perform all required laboratory tests.

10.6.7.1. Frequency of Testing

Samples for strength tests of each class of concrete placed each day shall be taken not less than once a day, nor less than once for each 120 m³ of concrete, nor less than once for each 500 m² of surface area for slabs or walls.

On a given project, if total volume of concrete is such that frequency of testing required by the previous paragraph would provide less than five strength tests for a given class of concrete, tests shall be made from at least five randomly selected batches or from each batch if fewer than five batches are used.

A strength test shall be the average of the strengths of two cylinders made from the same sample of concrete and tested at 28 days or at test age designated for determination of $f'_c$.

10.6.7.2. Laboratory-Cured Specimens

Samples for strength tests shall be taken in accordance with "Method of Sampling Freshly Mixed Concrete" (ASTM C 172).

Cylinders for strength tests shall be molded and laboratory-cured in accordance with "Practice for Making and Curing Concrete Test Specimens in the Field" (ASTM C 31) and tested in accordance with "Test Method for Compressive Strength of Cylindrical Concrete Specimens" (ASTM C 39)
Strength level of an individual class of concrete shall be considered satisfactory if both of the following requirements are met:

a) Every arithmetic average of any three consecutive strength tests equals or exceeds $f'_{c}$

b) No individual strength test (average of two cylinders) falls below $f'_{c}$ by more than 3.5 MPa when $f'_{c}$ is 35 MPa or less; or by more than $0.10 \times f'_{c}$ when $f'_{c}$ is more than 35 MPa.

If either of these requirements are not met, steps shall be taken to increase the average of subsequent strength test results. Requirements of Article 10.6.7.4, "Investigation of Low-strength test results" shall be observed if requirement of Point b before is not met.

10.6.7.3. Field-Cured Specimens

If required by the bridge official, results of strength tests of cylinders cured under field conditions shall be provided.

Field-cured cylinders shall be cured under field conditions in accordance with "Practice for Making and Curing Concrete Test Specimens in the Field" (ASTM C 31).

Field-cured test cylinders shall be molded at the same time and from the same samples as laboratory-cured test cylinders.

Procedures for protecting and curing concrete shall be improved when strength of field-cured cylinders at test age designated for determination of $f'_{c}$ is less than 85 percent of that of companion laboratory-cured cylinders. The eighty-five percent (85%) limitation shall not apply if field-cured strength exceeds $f'_{c}$ by more than 3.5 MPa.

10.6.7.4. Investigation of Low-Strength Test Results

If any strength test of laboratory-cured cylinders falls below specified value of $f'_{c}$ by more than the values given in Article 10.6.7.2(b), or if tests of field-cured cylinders indicate deficiencies in protection and curing (See Article 10.6.7.3), steps shall be taken to assure that load-carrying capacity of the structure is not jeopardized.

If the likelihood of low-strength concrete is confirmed and calculations indicate that load-carrying capacity is significantly reduced, tests of cores drilled from the area in question in accordance with "Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete" (ASTM C 42M) shall be permitted. In such cases, three cores shall be taken for each strength test that falls below the values given in Article 10.6.7.2(b).

Cores shall be prepared for transport and storage by wiping drilling water from their surfaces and placing the cores in watertight bags or containers immediately after drilling. Cores shall be tested no earlier than 48 h and not later than 7 days after coring unless approved by the registered design professional.

Concrete in an area represented by core tests shall be considered structurally adequate if the average of three cores is equal to at least eighty-five percent (85%) of $f'_{c}$ and if no single core is less than seventy-five percent (75%) of $f'_{c}$. Additional testing of cores extracted from locations represented by erratic core strength results shall be permitted.

If the precedent criteria are not met and if the structural adequacy remains in doubt, the Engineer shall order a strength evaluation.
10.6.7.5. Precast Concrete Cured By the Waterproof Cover Method, Steam, or Radiant Heat

When a precast concrete member is cured by the waterproof cover method, steam or radiant heat, the compressive strength test cylinders made for any of the above purposes shall be cured under conditions similar to the member. Such concrete shall be considered to be acceptable whenever a test indicates that the concrete has reached the specified compressive strength provided such strength is reached no later than the specified age for the compressive strength.

Test cylinders shall be cured by only one of the following methods:
- For concrete with specified design compressive strengths less than or equal to 40 MPa, test cylinders shall be stored next to the member and under the same covers such that the cylinders are exposed to the same temperature conditions as the member.
- For all specified concrete strengths, test cylinders shall be match-cured in chambers in which the temperature of the chamber is correlated with the temperature in the member prior to release of the prestressing strands. Temperatures of the chamber and member shall be verified by use of temperature sensors in the chamber and member. Unless specified otherwise, temperature sensors in I-beams shall be located at the center of gravity of the bottom flange. For other members, the temperature sensors shall be located at the center of the thickest section. The location shall be specified in the contract documents. After release of the prestressing strands, cylinders shall be stored in a similar temperature and humidity environment as the member.

10.7. Protection Of Concrete From Environmental Conditions

10.7.1. General

Precautions shall be taken as needed to protect concrete from damage due to weather or other environmental conditions during placing and curing periods.

10.7.2. Rain Protection

Under conditions of rain, the placing of concrete shall not commence or shall be stopped unless adequate protection is provided to prevent damage to the surface mortar or damaging flow or wash of the concrete surface.

10.7.3. Sulfate Exposures

Concrete to be exposed to sulfate-bearing groundwater or soils shall conform to the requirements of Table 10.6 or shall be concrete prepared with a cement that provides sulfate resistance and that has a maximum water-cementitious materials ratio, minimum cementitious materials content and minimum compressive strength from Table 10.6.
Table 10.6: Requirements for Concrete Exposed to Sulfate-Bearing Soils or Water

<table>
<thead>
<tr>
<th>Sulfate exposure</th>
<th>Water soluble sulfate (SO₄) in soil, percent by weight</th>
<th>Sulfate (SO₄) in water, ppm</th>
<th>Cement type</th>
<th>Maximum water-cementitious materials ratio, by weight</th>
<th>Minimum cementitious materials content, kg/m³</th>
<th>Minimum $f'_c$, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>0.00≤SO₄&lt;0.10</td>
<td>0≤SO₄&lt;150</td>
<td></td>
<td>(1)</td>
<td>(1)</td>
<td>(1)</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.10≤SO₄&lt;0.20</td>
<td>150≤SO₄&lt;1500</td>
<td>II</td>
<td>0.50</td>
<td>330</td>
<td>28</td>
</tr>
<tr>
<td>Severe+</td>
<td>0.20≤SO₄&lt;2.00</td>
<td>1500≤SO₄≤10,000</td>
<td>V</td>
<td>0.45</td>
<td>350</td>
<td>30</td>
</tr>
<tr>
<td>Very severe(2)</td>
<td>SO₄≥2.00</td>
<td>SO₄&gt;10,000</td>
<td>V plus pozzolan(3)</td>
<td>0.45</td>
<td>350</td>
<td>30</td>
</tr>
</tbody>
</table>

Notes: (1) As per other requirements and contract documents.
(2) If sulfate ions are associated with magnesium ions, supplementary protection, such as application of a barrier coating, is required.
(3) Pozzolan that conforms to relevant ASTM standards or that is shown to improve the sulfate resistance by service records should only be used.

10.7.4. Corrosion Protection of Reinforcement

For corrosion protection of reinforcement in concrete, maximum water-soluble chloride ion concentrations in hardened concrete at ages from 28 to 42 days contributed from the concrete ingredients including water, aggregates, cementitious materials, and admixtures shall not exceed the limits of Table 10.7, when testing is performed to determine the water-soluble chloride ion content, test procedures shall conform to ASTM C 1218.

Table 10.7: Maximum Chloride Ion Content for Corrosion Protection of Reinforcement

<table>
<thead>
<tr>
<th>Type of Member</th>
<th>Maximum water-soluble chloride ion (c£⁻) in concrete, percent by weight of cement*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prestressed concrete</td>
<td>0.06</td>
</tr>
<tr>
<td>Reinforced concrete exposed to chloride in service</td>
<td>0.15</td>
</tr>
<tr>
<td>Reinforced concrete that will be dry or protected from moisture in service</td>
<td>1.00</td>
</tr>
<tr>
<td>Other reinforced concrete construction</td>
<td>0.30</td>
</tr>
</tbody>
</table>

* Determined according to ASTM C 1218.

If concrete with reinforcement will be exposed to chlorides from soil, groundwater, seawater, or spray from these sources, requirements of Table 10.8 for water cementitious materials ratio, cementitious materials content, cement type and concrete strength, and the minimum cover over reinforcing steel requirements of Article 10.8 shall be satisfied.

For the permanently submerged, tidal, splash and spray zones of marine structures, the requirements for very severe exposure in Table 10.8 shall be satisfied.

For concrete structures near to or on the coast and exposed to airborne salt but not in direct contact with seawater, the requirements for severe exposure in Table 10.8 shall be satisfied.
For superstructures in coastal areas and not directly exposed to airborne salt, the requirements for moderate exposure in [Table 10.8] shall be satisfied.

Table 10.8: Requirements for Concrete Exposed to Chloride-Bearing Soil and Water

<table>
<thead>
<tr>
<th>Chloride exposure</th>
<th>Water soluble chloride (cℓ⁻) in soil, percent by weight</th>
<th>Water soluble chloride (cℓ⁻) in water, ppm</th>
<th>Cement type</th>
<th>Maximum water-cementitious materials ratio</th>
<th>Minimum cementitious materials content, kg/m³</th>
<th>Minimum ( f_c' ), MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible</td>
<td>Up to 0.05</td>
<td>Up to 500</td>
<td>___(1)</td>
<td>___(1)</td>
<td>___(1)</td>
<td>___(1)</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.05 to 0.1</td>
<td>500 to 2,000</td>
<td>___(1)</td>
<td>0.50</td>
<td>330</td>
<td>28</td>
</tr>
<tr>
<td>Severe</td>
<td>0.1 to 0.5</td>
<td>2,000 to 10,000</td>
<td>I</td>
<td>0.45</td>
<td>350</td>
<td>30</td>
</tr>
<tr>
<td>Very severe</td>
<td>More than 0.5</td>
<td>More than 10,000</td>
<td>I + pozzolan(2)</td>
<td>0.40</td>
<td>370</td>
<td>35</td>
</tr>
</tbody>
</table>

Notes:
(1) As per other requirements and contract documents.
(2) Pozzolan that conforms to relevant standards shall only be used.

10.7.5. Sulfate plus Chloride Exposures

If concrete is exposed to both chlorides and sulfates, the lowest applicable maximum water-cementitious materials ratio and highest minimum cementitious materials content of [Table 10.6] and [Table 10.8] shall be selected. The corresponding highest \( f_c' \) shall be the governing value for quality control purposes. The cement type shall be the one required by Table 10.8.

10.7.6. Sabkha Exposures

Concrete structures exposed to sabkha shall meet the requirements for very severe exposure in [Table 10.8], except that the water-cementitious materials ratio shall not be more than 0.35. In addition, the exposed surfaces shall be protected by appropriate means, such as tanking or epoxy-based coating.

10.7.7. Salt Weathering

Concrete structures amenable to salt weathering shall be protected by applying an appropriate barrier coating.

10.7.8. Hot-Weather Protection

The temperature of the concrete mixture immediately before placement shall be between ten degrees Celsius (10°C) and thirty-five degree Celsius (35°C), except as otherwise provided herein.

When the ambient temperature is above thirty-five degree Celsius (35°C), the forms, reinforcing steel, steel beam flanges, and other surfaces which will come in contact with the mix shall be cooled to below thirty-five degree Celsius (35°C) by means of a water spray or other approved methods.

The temperature of the concrete at time of placement shall be maintained within the specified temperature range by any combination of the following:
- Shading the materials storage areas or the production equipment.
Cooling the aggregates by sprinkling with water which conforms to the requirements of Article 10.4.4, "Water".

Cooling the aggregates or water by refrigeration or replacing a portion or all of the mix water with ice that is flaked or crushed to the extent that the ice will completely melt during mixing of the concrete.

Injecting liquid nitrogen.

10.7.9. Special Requirements for Bridge Decks

When placing concrete in bridge decks or other exposed slabs, evaporation rate shall be limited to less than 0.5 kg per square meter per hour.

When necessary, take one or more of the following actions:

1) Construct windbreaks or enclosures to effectively reduce the wind velocity throughout the area of placement.

2) Use fog sprayers upwind of the placement operation to effectively increase the relative humidity.

3) Reduce the temperature of the concrete according to Article 10.7.8 above.

During periods of low humidity, wind, or high temperatures and prior to the application of curing materials, concrete being placed and finished for bridge decks shall be protected from damage due to rapid evaporation. Such protection shall be adequate to prevent premature crusting of the surface or an increase in drying cracking. Such protection shall be provided by raising the humidity of the surrounding air with fog sprayers operated upwind of the deck, by employing wind-breaks or sun-shades, additionally reducing the temperature of the concrete, scheduling placement during the cooler times of days or nights, or any combination thereof.

For bridge decks that are located over or adjacent to salt water or when specified in the contract documents, the maximum temperature of the concrete at time of placement shall be twenty-seven degree Celsius (27°C).

10.8. Concrete Protection for Reinforcement

10.8.1. Cast-in-place concrete (non-prestressed)

The following minimum concrete cover shall be provided for reinforcement, but shall not be less than required by Articles 10.8.5 and 10.8.7.
Table 10.9: Minimum Reinforcement Cover (mm) for Cast-in-Place Concrete (non-prestressed).

<table>
<thead>
<tr>
<th>Reinforcement Location</th>
<th>Minimum Cover (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete cast against and permanently exposed to earth</td>
<td>75</td>
</tr>
<tr>
<td>Concrete exposed to earth or weather:</td>
<td></td>
</tr>
<tr>
<td>Dia 20 mm bars and larger</td>
<td>50</td>
</tr>
<tr>
<td>Dia 18 mm bar, WD 12.0 wire, and smaller</td>
<td>40</td>
</tr>
<tr>
<td>Concrete not exposed to weather or in contact with ground:</td>
<td></td>
</tr>
<tr>
<td>Slabs, walls, joists:</td>
<td></td>
</tr>
<tr>
<td>Dia 40 mm bars and larger</td>
<td>40</td>
</tr>
<tr>
<td>Bars with diameters smaller than 40 mm</td>
<td>20</td>
</tr>
<tr>
<td>Beams, Columns:</td>
<td></td>
</tr>
<tr>
<td>Primary reinforcement, ties, stirrups, spirals</td>
<td>40</td>
</tr>
<tr>
<td>Shells, folded plate members:</td>
<td></td>
</tr>
<tr>
<td>Dia 20 mm bar and larger</td>
<td>20</td>
</tr>
<tr>
<td>Dia 18 mm WD 12.0 wire, and smaller</td>
<td>15</td>
</tr>
</tbody>
</table>

10.8.2. Cast-in-place concrete (prestressed)

The following minimum concrete cover shall be provided for prestressed and non-prestressed reinforcement, ducts, and end fittings, but shall not be less than required by Articles 10.8.5 and 10.8.7.

Table 10.10: Minimum reinforcement cover (mm) for cast-in-place concrete (prestressed).

<table>
<thead>
<tr>
<th>Reinforcement Location</th>
<th>Minimum Cover (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete cast against and permanently exposed to earth</td>
<td>75</td>
</tr>
<tr>
<td>Concrete exposed to earth or weather:</td>
<td></td>
</tr>
<tr>
<td>Wall panels, slabs, joists</td>
<td>25</td>
</tr>
<tr>
<td>Other members</td>
<td>40</td>
</tr>
<tr>
<td>Concrete not exposed to weather or in contact with ground:</td>
<td></td>
</tr>
<tr>
<td>Slabs, walls, joists:</td>
<td></td>
</tr>
<tr>
<td>Bars with diameters smaller than 40 mm</td>
<td>40</td>
</tr>
<tr>
<td>Beams, Columns:</td>
<td>20</td>
</tr>
<tr>
<td>Primary reinforcement</td>
<td>40</td>
</tr>
<tr>
<td>Ties, stirrups, spirals</td>
<td>25</td>
</tr>
<tr>
<td>Shells, folded plate members:</td>
<td></td>
</tr>
<tr>
<td>Dia. 18 mm bar, WD 12.0 wire, and smaller</td>
<td>10</td>
</tr>
<tr>
<td>Other reinforcement = (d_b) but not less than</td>
<td>20</td>
</tr>
</tbody>
</table>
10.8.3. Precast concrete (manufactured under plant control conditions)

The following minimum concrete cover shall be provided for prestressed and non-prestressed reinforcement, ducts, and end fittings, but shall not be less than required by Articles 10.8.5 and 10.8.7.

Table 10.11: Minimum reinforcement cover (mm) for precast concrete (manufactured under plant control conditions).

<table>
<thead>
<tr>
<th>Concrete exposed to earth or weather:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall panels:</td>
<td></td>
</tr>
<tr>
<td>Dia. 40 mm bars and larger and prestressing tendons larger than 40 mm diameter.</td>
<td>75</td>
</tr>
<tr>
<td>Dia. 36 mm bar and smaller, prestressing 40 mm diameter and smaller, WD 12.0 wire and smaller.</td>
<td>20</td>
</tr>
<tr>
<td>Other members:</td>
<td></td>
</tr>
<tr>
<td>Dia. 40 mm bars and larger bars and prestressing tendons larger than 40 mm diameter.</td>
<td>50</td>
</tr>
<tr>
<td>Dia. 20 mm through Dia. 36 mm bars, prestressing tendons larger than 16 mm diameter through 40 mm diameter.</td>
<td>40</td>
</tr>
<tr>
<td>Dia. 16 mm bar and smaller, prestressing 16 mm diameter and smaller, WD 12.0 wire, and smaller.</td>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concrete not exposed to weather or in contact with ground:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Slabs, walls, joists:</td>
<td></td>
</tr>
<tr>
<td>Dia. 40 mm bars and larger and prestressing tendons larger than 40 mm diameter</td>
<td>30</td>
</tr>
<tr>
<td>Prestressing tendons 40 mm diameter and smaller</td>
<td>20</td>
</tr>
<tr>
<td>Dia. 36 mm bar and smaller, WD 12.0 wire, and smaller</td>
<td>15</td>
</tr>
<tr>
<td>Beams, columns:</td>
<td></td>
</tr>
<tr>
<td>Primary reinforcement = ( d_b ) but not less than and need not exceed 40</td>
<td>16</td>
</tr>
<tr>
<td>Ties, stirrups, spirals</td>
<td>10</td>
</tr>
<tr>
<td>Shells, folded plate members:</td>
<td>20</td>
</tr>
<tr>
<td>Prestressing tendons:</td>
<td></td>
</tr>
<tr>
<td>Dia. 20 mm bar and larger</td>
<td>15</td>
</tr>
<tr>
<td>Dia. 16 mm bar and smaller, WD 12.0 wire, and smaller</td>
<td>10</td>
</tr>
</tbody>
</table>

10.8.4. Bundled bars

For bundled bars, minimum concrete cover shall be equal to the equivalent diameter of the bundle, but need not be greater than 50 mm; except for concrete cast against and permanently exposed to earth, where minimum cover shall be 75 mm.
10.8.5. Corrosive environments

In corrosive environments or other severe exposure conditions, the amount of concrete protection shall be suitably increased, and denseness and non-porosity of protecting concrete shall be considered, or other protection shall be provided.

For prestressed concrete members exposed to corrosive environments or other severe exposure conditions, minimum cover to the prestressed reinforcement shall be increased fifty percent (50%). This requirement shall be permitted to be waived if the pre-compressed tensile zone is not in tension under sustained loads.

10.8.6. Future extensions

Exposed reinforcement, inserts, and plates intended for bonding with future extensions shall be protected from corrosion.

10.8.7. Fire protection

When Chapter 4 of SBC 801 requires a thickness of cover for fire protection greater than the minimum concrete cover specified in Article 10.8, such greater thicknesses shall be used.

10.9. Handling and Placing of Concrete

10.9.1. General

Concrete shall be handled, placed, and consolidated by methods that will not cause segregation of the mix and will result in a dense homogeneous concrete that is free of voids and rock pockets. The methods used shall not cause displacement of reinforcing steel or other materials to be embedded in the concrete. Concrete shall be placed and consolidated prior to initial set and in no case shall not exceed the initial setting time after the cement was added to the mix and shall satisfy the requirements of Table 10.5. Concrete shall not be retempered.

Concrete shall not be placed until the forms, all materials to be embedded, and, for spread footings, the adequacy of the foundation material, have been inspected and approved by the Engineer. All mortar from previous placements, debris, and foreign material shall be removed from the forms and steel prior to commencing placement. The forms and subgrade shall be thoroughly moistened with water immediately before concrete is placed against them. Temporary form spreader devices may be left in place until concrete placement precludes their need, after which they shall be removed.

Placement of concrete for each section of the structure shall be done continuously without interruption between planned' construction or expansion joints. The delivery rate, placing sequence, and methods shall be such that fresh concrete is always placed and consolidated against previously placed concrete before initial set has occurred in the previously placed concrete.

During and after placement of concrete, care shall be taken not to injure the concrete or break the bond with reinforcing steel. Workers shall not walk in fresh concrete. Platforms for workers and equipment shall not be supported directly on any reinforcing steel. Once the concrete is set, forces shall not be applied to the forms or to reinforcing bars which project from the concrete until the concrete is of sufficient strength to resist damage.
10.9.2. Sequence of Placement

Whenever a concrete placement plan or schedule is specified or approved, the sequence of placement shall conform to the plan. Unless otherwise specifically permitted by the contract documents, the requirements of the following paragraphs shall apply.

10.9.2.1. Vertical Members

Concrete for columns, substructure and culvert walls, and other similar vertical members shall be placed and allowed to set and settle for a period of time before concrete for integral horizontal members, such as caps, slabs, or footings, is placed. Such period shall be adequate to allow completion of settlement due to loss of bleed water and shall be not less than 12 h for vertical members over 4.5 m in height and not less than 30 min for members over 1.5 m, but not over 4.5 m in height. When friction collars or falsework brackets are mounted on such vertical members and unless otherwise approved, the vertical member shall have been in place at least seven days and shall have attained its specified strength before loads from horizontal members are applied.

10.9.2.2. Superstructures

Unless otherwise permitted, no concrete shall be placed in the superstructure until substructure forms have been stripped sufficiently to determine the character of the supporting substructure concrete.

Concrete for T-beam or deck girder spans whose depth is less than 1.2 m may be placed in one continuous operation or may be placed in two separate operations; first, to the top of the girder stems, and second, to completion. For T-beam or deck girder spans whose depth is 1.2 m or more, and unless the falsework is non-yielding, such concrete shall be placed in two operations, and at least five days shall elapse after placement of stems before the top deck slab is placed.

Concrete for box girders may be placed in two or three separate operations consisting of bottom slab, girder stems, and top slab. In either case, the bottom slab shall be placed first and, unless otherwise permitted by the Engineer, the top slab shall not be placed until the girder stems have been in place for at least five days.

10.9.2.3. Arches

The concrete in arch rings shall be placed in such a manner as to load the centering uniformly and symmetrically. Arch rings shall be cast in transverse sections of such size that each section can be cast in a continuous operation. The arrangement of the sections and the sequence of placing shall be as approved and shall be such as to avoid the creation of initial stress in the reinforcement. The sections shall be bonded together by suitable keys or dowels. Arch barrels for culverts and, unless prohibited by the special provisions, other arches may be cast in a single continuous operation.

10.9.2.4. Tunnels

Tunnel concrete shall be placed by pumping and discharged into the work through a pipe inserted into the formed space. The discharge line shall be graduated to indicate the depth of filling at any time. Special care shall be taken to force concrete into all irregularities in work surfaces and to completely fill tunnel walls and crown. Placing equipment shall be operated only by experienced operators. The Contractor shall vibrate pumped concrete. Concrete shall not be pumped through aluminum alloy pipe.
10.9.2.5. Placing of Concrete for Tunnels on Rock Surfaces

Rock surfaces against or upon which concrete is to be placed shall be clean, free of oil, and other objectionable coatings, water, mud, debris, dummy rock and loose semi-detached or unsound fragments, and shall be sufficiently rough to assure satisfactory bond with the concrete. Discontinuities shall be cleaned to hard rock on the sides, and to a depth that is approved by the Engineer. All overbreak beyond the excavation limit shown on the contract documents shall be backfilled with shotcrete or concrete at the Contractor's expense.

10.9.2.6. Box Culverts

In general, the base slab or footings of box culverts shall be placed and allowed to set before the remainder of the culvert is constructed. For culverts whose wall height is 1.5 m or less, the sidewalls and top slab may be placed in one continuous operation. For higher culvert walls, the requirements for vertical members shall apply.

10.9.2.7. Precast Elements

The sequence of placement for concrete in precast elements shall be such that sound, well consolidated concrete that is free of settlement or shrinkage cracks is produced throughout the member.

10.9.3. Placing Methods

10.9.3.1. General

Concrete shall be placed as nearly as possible in its final position, and the use of vibrators for extensive shifting of the weight of fresh concrete will not be permitted.

Concrete shall be placed in horizontal layers of a thickness not exceeding the capacity of the vibrator to consolidate the concrete and merge it with the previous lift. In no case shall the depth of a lift exceed 600 mm. The rate of concrete placement shall not exceed that assumed for the design of the forms as corrected for the actual temperature of the concrete being placed.

When placing operations would involve dropping the concrete more than 1.5 m, the concrete shall be dropped through a tube fitted with a hopper head or through other approved devices, as necessary to prevent segregation of the mix and spattering of mortar on steel and forms above the elevation of the lift being placed. This requirement shall not apply to cast-in-place piling when concrete placement is completed before initial set occurs in the first placed concrete.

10.9.3.2. Equipment

All equipment used to place concrete shall be of adequate capacity and designed and operated so as to prevent segregation of the mix or loss of mortar. Such equipment shall not cause vibrations that might damage the freshly placed concrete. No equipment shall have aluminum parts which come in contact with the concrete. Between uses, the mortar coating inside of placing equipment which sets or dries out shall be cleaned from the equipment before use is resumed.

Chutes shall be lined with smooth watertight material and, when steep slopes are involved, shall be equipped with baffles or reverses.

Concrete pumps shall be operated such that a continuous stream of concrete without air pockets is produced. When pumping is completed, the concrete remaining in the
pipeline, if it is to be used, shall be ejected in such a manner that there will be no contamination of the concrete or separation of the ingredients.

Conveyor belt systems shall not exceed a total length of 168 m, measured from end to end of the total assembly. The belt assembly shall be so arranged that each section discharges into a vertical hopper arrangement to the next section. To keep segregation to a minimum, scrapers shall be situated over the hopper of each section so as to remove mortar adhering to the belt and to deposit it into the hopper. The discharge end of the conveyor belt system shall be equipped with a hopper and a chute or suitable deflectors to cause the concrete to drop vertically to the deposit area.

10.9.4. Consolidation

All concrete, except concrete placed under water and concrete otherwise exempt, shall be consolidated by mechanical vibration immediately after placement.

Except as noted herein, vibration shall be internal.

External form vibrators may be used for thin sections when the forms have been designed for external vibration.

Vibrators shall be of approved type, design, and of a size appropriate for the work. They shall be capable of transmitting vibration to the concrete at frequencies of not less than 75 Hz.

The Contractor shall provide a sufficient number of vibrators to properly compact each batch of concrete immediately after it is placed in the forms. The Contractor shall also have at least one spare vibrator immediately available in case of breakdown.

Vibrators shall be manipulated so as to thoroughly work the concrete around the reinforcement and embedded fixtures and into the comers and angles of the forms. Vibration shall be applied at the point of deposit and in the area of freshly deposited concrete. The vibrators shall be inserted and withdrawn out of the concrete slowly. The vibration shall be of sufficient duration and intensity to thoroughly consolidate the concrete but shall not be continued so as to cause segregation. Vibration shall not be continued at anyone point to the extent that localized areas of grout are formed. Application of vibrators shall be at points uniformly spaced and not farther apart than 1.5 times the radius over which the vibration is visibly effective.

Vibration shall not be applied either directly to, or through the reinforcement to, sections or layers of concrete which have hardened to the degree that the concrete ceases to be plastic under vibration. Vibrators shall not be used to transport concrete in the forms.

Where immersion-type vibrators are used to consolidate concrete around epoxy-coated reinforcing steel, the vibrators shall be equipped with rubber or other nonmetallic coating.

Vibration shall be supplemented by such spading as is necessary to ensure smooth surfaces and dense concrete along form surfaces and in corners and locations impossible to reach with the vibrators.

When approved by the Engineer, concrete for small non-critical elements may be consolidated by the use of suitable rods and spades.
10.9.5. Underwater Placement

10.9.5.1. General

Only concrete used in cofferdams to seal out water may be placed under water, unless otherwise specified in the contract documents or specifically approved by the Engineer. If other than Class S concrete is to be placed under water, the minimum cement content of the mix shall be increased by ten percent to compensate for loss due to wash.

To prevent segregation, concrete placed under water shall be carefully placed in a compact mass, in its final position, by means of a tremie, concrete pump, or other approved method and shall not be disturbed after being deposited. Still water shall be maintained at the point of deposit and the forms under water shall be watertight. Cofferdams shall be vented during the placement and cure of concrete to equalize the hydrostatic pressure and thus prevent flow of water through the concrete.

Concrete placed under water shall be placed continuously from start to finish. The surface of the concrete shall be kept as nearly horizontal as practicable. To ensure thorough bonding, each succeeding layer of seal shall be placed before the preceding layer has taken initial set. For large pours, more than one tremie or pump shall be used to ensure compliance with this requirement.

10.9.5.2. Equipment

A tremie shall consist of a watertight tube having a diameter of not less than 250 mm and fitted with a hopper at the top. The tremies shall be supported so as to permit free movement of the discharge end over the entire top surface of the work and so as to permit rapid lowering when necessary to retard or stop the flow of concrete. The discharge end shall be sealed closed at the start of work so as to prevent water from entering the tube before the tube is filled with concrete. After placement has started, the tremie tube shall be kept full of concrete to the bottom of the hopper. If water enters the tube after placement is started, the tremie shall be withdrawn, the discharge end resealed, and the placement restarted. When a batch is dumped into the hopper, the flow of concrete shall be induced by slightly raising the discharge end, always keeping it in the deposited concrete. The flow shall be continuous until the work is completed. When cofferdam struts prevent lateral movement of tremies, one tremie shall be used in each bay.

Concrete pumps used to place concrete under water shall include a device at the end of the discharge tube to seal out water while the tube is first being filled with concrete. Once the flow of concrete is started, the end of the discharge tube shall be kept full of concrete and below the surface of the deposited concrete until placement is completed.

10.9.5.3. Clean-up

Dewatering may proceed after test specimens cured under similar conditions indicate that the concrete has sufficient strength to resist the expected loads. All laitance or other unsatisfactory materials shall be removed from the exposed surface by scraping, chipping, or other means which will not injure the surface of the concrete before placing foundation concrete.
10.10. Construction Joints

10.10.1. General

Construction joints shall be made only where specified in the contract documents, or shown in the pouring schedule, unless otherwise approved. All planned reinforcing steel shall extend uninterrupted through joints. In the case of emergency, construction joints shall be placed as directed by the Engineer and, if directed, additional reinforcing steel dowels shall be placed across the joint. Such additional steel shall be furnished and placed at the Contractor's expense.

10.10.2. Horizontal Joints

Generally, horizontal joints shall be made by pouring the concrete slightly above the grade of the construction joint, and after the surface has reached its final set, the surface shall be prepared as outlined in Article 10.10.4, "Bonding". Insert form work shall be used to obtain neat, horizontal lines.

10.10.3. Vertical Joints

Vertical joints shall be formed with substantial bulkheads or headers as required. Feather edged joints will not be permitted.

10.10.4. Bonding

Unless otherwise specified in the contract documents, horizontal joints may be made without keys, and vertical joints shall be constructed with shear keys. Surfaces of fresh concrete at horizontal construction joints shall be rough floated sufficiently to thoroughly consolidate the surface and intentionally left in a roughened condition. Shear keys shall consist of formed depressions in the surface covering approximately one-third of the contact surface. The forms for keys shall be beveled so that removal will not damage the concrete.

All construction joints shall be cleaned of surface laitance, curing compound, and other foreign materials before fresh concrete is placed against the surface of the joint. Abrasive blast or other approved methods shall be used to clean horizontal construction joints to the extent that clean aggregate is exposed. All construction joints shall be flushed with water and allowed to dry to a surface dry condition immediately prior to placing concrete.

10.10.5. Bonding and Dowelling to Existing Structures

When the contract documents specify that new concrete be bonded to existing concrete structures, the existing concrete shall be cleaned and flushed as specified in Article 10.10.4, "Bonding". When the contract documents show reinforcing dowels grouted into holes drilled in the existing concrete at such construction joints, the holes shall be drilled by methods that will not shatter or damage the concrete adjacent to the holes. The diameters of the drilled holes shall be 6 mm larger than the nominal diameter of the dowels unless shown otherwise in the contract documents. The grout shall be a neat cement paste of Portland cement and water. The water content shall be not more than 0.36 liter/kg of cement. Retempering of grout will not be permitted. Immediately prior to placing the dowels, the holes shall be cleaned of dust and other deleterious materials, shall be thoroughly saturated with water, shall have all free water removed, and the holes shall be dried to a saturated surface-dry condition. Sufficient grout shall be placed in the holes so that no voids remain after the dowels are inserted.
Grout shall be cured for a period of at least three days or until dowels are encased in concrete.

When specified in the contract documents or approved by the Engineer, epoxy may be used in lieu of Portland cement grout for the bonding of dowels in existing concrete. When used, epoxy shall be mixed and placed in accordance with the Manufacturer's recommendations.

10.10.6. Forms at Construction Joints

When forms at construction joints overlap previously placed concrete, they shall be retightened before depositing new concrete. The face edges of all joints that are exposed to view shall be neatly formed with straight bulkheads or grade strips, or otherwise carefully finished true to line and elevation.

10.11. Expansion and Contraction Joints

10.11.1. General

Expansion and contraction joints shall be constructed at the locations and in accordance with the details specified in the contract documents. Such joints include open joints, filled joints, joints sealed with sealants or water stops, joints reinforced with steel armor plates or shapes, and joints with combinations of these features.

When preformed elastomeric compression joint seals or bridge deck joint seal assemblies are required, they shall conform to the requirements of Section 17, "Bridge Deck Joint Seals."

10.11.2. Materials

10.11.2.1. Premolded Expansion Joint Fillers

Premolded fillers shall conform to one of the following specifications:


- Specification for Preformed Sponge Rubber and Cork Expansion Joint Fillers for Concrete Paving and Structural Construction, AASHTO M 153 (ASTM D 1752). Type II (cork) shall not be used when resiliency is required.

- Specification for Preformed Expansion Joint Filler for Concrete, AASHTO M 33 (ASTM D 994).

10.11.2.2. Polystyrene Board Fillers

Board fillers shall be expanded polystyrene with a minimum flexural strength of 0.24 MPa, as determined by ASTM C 203, and a compressive yield strength of between 0.1 to 0.3 MPa at five percent compression. When specified in the contract documents, or required to prevent damage during concrete placement, the surface of polystyrene board shall be faced with 3-mm thick hardboard conforming to ANSI A135.4.

10.11.2.3. Contraction Joint Material

Material placed in contraction joints shall consist of asphalt saturated felt paper or other approved bond breaking material.
10.11.2.4. Pourable Joint Sealants (2)

Pourable sealants for placement along the top edges of contraction or filled expansion joints shall conform to one of the following:

- Hot-poured sealants shall conform to AASHTO M 282 (ASTM D 3406), except that when the sealant will be in contact with asphaltic material, it shall conform to AASHTO M 301.
- Cold-poured sealant shall be silicone type, conforming to Federal Specification TT-S-1543, Class A. The sealant shall be a one-part, low-modulus silicone rubber type with an ultimate elongation of one thousand two hundred percent (1200%).
- Polyethylene foam strip, for use when shown in the contract documents, shall be of commercial quality with a continuous, impervious, glazed top surface, suitable for retaining the liquid sealant at the proper elevation in the joint while hardening.

10.11.2.5. Metal Armor

Expansion joint armor assemblies shall be fabricated from steel in conformance with the requirements of Section 22, "Miscellaneous Metal". Assemblies shall be accurately fabricated and straightened at the shop after fabrication and galvanizing as necessary to conform to the concrete section.

10.11.2.6. Waterstops

Waterstops shall be of the type, size, and shape specified in the contract documents. They shall be dense, homogeneous, and without holes or other defects.

1. Rubber Waterstops

Rubber waterstops shall be formed from synthetic rubber made exclusively from neoprene, reinforcing carbon black, zinc oxide, polymerization agents, and softeners. This compound shall contain not less than seventy percent (70%) by volume of neoprene. The tensile strength shall not be less than 19 MPa with an elongation at breaking of six hundred percent (600%). The Shore Durometer indication (hardness) shall be between 50 and 60. After seven days in air at temperature of seventy degree Celsius plus or minus one degree Celsius (70±1°C) or after four days in oxygen at seventy degree Celsius plus or minus one degree Celsius (70±1°C) and 2 MPa pressure, the tensile strength shall not be less than sixty-five percent (65%) of the original.

Rubber waterstops shall be formed with an integral cross-section in suitable molds, so as to produce a uniform section with a permissible variation in dimension of ±0.8 mm. No splices will be permitted in straight strips. Strips and special connection pieces shall be well cured in a manner such that any cross-section shall be dense, homogeneous, and free from all porosity. Junctions in the special connection pieces shall be full molded. During the vulcanizing period, the joints shall be securely held by suitable clamps. The material at the splices shall be dense and homogeneous throughout the cross-section.

2. Polyvinyl Chloride Waterstops

Polyvinyl chloride (PVC) waterstops shall be manufactured by the extrusion process from an elastomeric plastic compound, the basic resin of which shall be PVC. The compound shall contain any additional resins, plasticizers, stabilizers, or other materials needed to ensure that, when the material is compounded, it will meet the performance requirements given in this specification. No reclaimed PVC or other material shall be used.
The material shall comply with the following physical requirements when tested under the indicated ASTM test method as mentioned in Table 10.12.

<table>
<thead>
<tr>
<th>Table 10.12: ASTM Test Method Requirements.</th>
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<tbody>
<tr>
<td>Specific Gravity</td>
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<td>Durometer Hardness</td>
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<td>Stiffness in Flexure</td>
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3. Copper Waterstops

Sheet copper shall conform to the Specifications for Copper Sheet, Strip, Plate, and Rolled Bar, AASHTO M 138M/M 138 (ASTM B 152/B 152M), and shall meet the Embrittlement Test of Section 10 of AASHTO M 138M/M 138 (ASTM B 152/B 152M).

4. Testing of Waterstop Material

The Manufacturer shall be responsible for the testing of all waterstop materials, either in company owned or affiliated laboratory or in a recognized commercial laboratory, and shall submit three certified copies of test results to the Engineer.

10.11.3. Installation

10.11.3.1. Open Joints

Open joints shall be constructed by the insertion and subsequent removal of a wood strip, metal plate, or other approved material. The insertion and removal of the template shall be accomplished without chipping or breaking the corners of the concrete. When not protected by metal armor, open joints in decks and sidewalks shall be finished with an edging tool. Upon completion of concrete finishing work, all mortar and other debris shall be removed from open joints.

10.11.3.2. Filled Joints

When filled joints are specified in the contract documents, Premolded-type fillers shall be used unless polystyrene board is specifically called for. Filler for each joint shall consist of as few pieces of material as possible. Abutting edges of filler material shall be accurately held in alignment with each other and tightly fit or taped as necessary to prevent the intrusion of grout. Joint filler material shall be anchored to one side of the joint by waterproof adhesive or other methods so as to prevent it from working out of the joint, but not interfere with the compression of the material.

10.11.3.3. Sealed Joints

Prior to installation of pourable joint sealants, all foreign material shall be removed from the joint, the filler material shall be cut back to the depth shown or approved, and the surface of the concrete that will be in contact with the sealant shall be cleaned by light sandblasting. When required, a polyethylene foam strip shall be placed in the joint to retain the sealant and isolate it from the filler material. The sealant materials shall
then be mixed and installed in accordance with the Manufacturer's directions. Any material that fails to bond to the sides of the joint within 24 h after placement shall be removed and replaced.

10.11.3.4. Waterstops

Adequate water stops of metal, rubber, or plastic shall be placed as specified in the contract documents. Where movement at the joint is provided for, the waterstops shall be of a type permitting such movement without damage. They shall be spliced, welded, or soldered to form continuous watertight joints.

Precautions shall be taken so that the water stops shall be neither displaced nor damaged by construction operations or other means. All surfaces of the water stops shall be kept free from oil, grease, dried mortar, or any other foreign matter while the water stop is being embedded in concrete. Means shall be used to insure that all portions of the water stop designed for embedment shall be tightly enclosed by dense concrete.

10.11.3.5. Expansion Joint Armor Assemblies

Armor assemblies shall be installed so the top surface matches the plane of the adjacent finished concrete surface throughout the length of the assembly. Positive methods shall be employed in placing the assemblies to keep them in correct position during the placing of the concrete. The opening at expansion joints shall be that designated in the contract documents at normal temperature or as directed by the Engineer for other temperatures and care shall be taken to avoid impairment of the clearance in any manner.

10.11.3.6. Sheet Packing, Preformed Pads and Board Fillers

Tempered hardboard shall conform to Federal Specification LLL-B-810, Type II, smooth one side, plain. Hardboard shall be three millimeters (3 mm) minimum thickness, unless shown or specified otherwise.

Expanded polystyrene shall be a commercially available polystyrene board. Expanded polystyrene shall have a flexural strength of 240 kPa, minimum, determined in conformance with the requirements in ASTM Designation: C 203, and a compressive yield strength of between 110 and 275 kPa, at five percent (5%) compression.

When shown on the contract documents, surfaces of expanded polystyrene shall be faced with hardboard. Hardboard shall be 3 mm minimum thickness, conforming to Federal Specification LLL-B-810, any type. Other facing materials may be used provided they furnish equivalent protection. Boards shall be held in place by nails, waterproof adhesive or other means approved by the Engineer.

10.12. Finishing Plastic Concrete

10.12.1. General

Unless otherwise specified in the contract documents, after concrete has been consolidated and prior to the application of cure, all surfaces of concrete that are not placed against forms shall be struck-off to the planned elevation or slope and the surface finished by floating with a wooden float sufficiently to seal the surface. While the concrete is still in a workable state, all construction and expansion joints shall be carefully tooled with an edger. Joint filler shall be left exposed.
10.12.2. Roadway Surface Finish

All bridge decks, approach slabs, and other concrete surfaces for use by traffic shall be finished to a smooth skid-resistant surface in accordance with this Article. During finishing operations, the Contractor shall provide suitable and adequate work bridges for proper performance of the work, including the application of fog sprays and curing compound, and for inspecting the work.

10.12.2.1. Striking Off and Floating

For bridge decks or top slabs of structures serving as finished pavements, use an approved power driven finishing machine equipped with a screed that oscillates in a transverse direction. If approved, use hand-finishing methods for irregular areas where the use of a machine is impractical. The finishing procedures should take the following into account:

- Strike off all surfaces using equipment supported by and traveling on screed rails or headers. Do not support rails within the limits of the concrete placement without approval.
- Set rails or headers on non-yielding supports so the finishing equipment operates without interruption over entire surface being finished. Extend rails beyond both ends of the scheduled concrete placement a sufficient distance to enable finishing machine to finish the concrete being placed.
- Set rails the entire length of steel girder superstructures.
- Adjust rails, headers, and strike-off equipment to the required profile and cross-section allowing for anticipated settlement, camber, and deflection of falsework.
- Before beginning delivery and placement of concrete, operate the finishing machine over the entire area to be finished to check for excessive rail deflections, deck thickness, reinforcing steel cover, and to verify proper operation of equipment. Make necessary corrections before concrete placement begins.
- After placing the concrete, operate finishing machine over the concrete as needed to obtain the required profile and cross-section. Keep a slight roll of excess concrete in front of the cutting edge of the screed at all times. Maintain this excess of concrete to the end of the pour or form and then remove and waste it. Adjust rails or headers as necessary to correct for unanticipated settlement or deflection.

10.12.2.2. Straightedging

After finishing as described above, the entire surface shall be checked by the Contractor with a 3 m metal straightedge operated parallel to the centerline of the bridge and shall show no deviation in excess of 3 mm from the testing edge of the straightedge. For deck surfaces that are to be overlaid with 25 mm or more of another material, such deviation shall not exceed 10 mm in 3 m. Deviations in excess of these requirements shall be corrected before the concrete sets. The checking operation shall progress by overlapping the straightedge at least one-half the length of the preceding pass.

10.12.2.3. Texturing

The surface shall be given a skid-resistant texture by either burlap or carpet dragging, brooming, tinning, or by a combination of these methods. The method employed shall be as specified in the contract documents or as approved by the Engineer. Surfaces that are to be covered with a waterproofing membrane deck seal
shall not be coarse textured. They shall be finished to a smooth surface, free of mortar ridges and other projections.

This operation shall be done after floating and at such time and in such manner that the desired texture will be achieved while minimizing displacement of the larger aggregate particles.

1. Dragged

If the surface texture is to be a drag finish, the surface shall be finished by dragging a seamless strip of damp burlap over the full width of the surface. The burlap drag shall consist of sufficient layers of burlap and have sufficient length in contact with the concrete to slightly groove the surface and shall be moved forward with a minimum bow of the lead edge. The drag shall be kept damp, clean, and free of particles of hardened concrete. As an alternative to burlap, the Engineer may approve or direct that carpet or artificial turf of approved type and size be substituted.

2. Broomed

If the surface texture is to be a broom finish, the surface shall be broomed when the concrete has hardened sufficiently. The broom shall be of an approved type. The strokes shall be square across the slab, from edge to edge, with adjacent strokes slightly overlapped, and shall be made by drawing the broom without tearing the concrete but so as to produce regular corrugations not over 3 mm in depth. The surface as thus finished shall be free from porous spots, irregularities, depressions, and small pockets or rough spots such as may be caused by the accidental disturbing of particles of coarse aggregate embedded near the surface during the final brooming operation.

3. Tined

If the surface is to be tined, the tinning shall be in a transverse direction using a wire broom, comb, or finned float having a single row of tines or fins. The tinning grooves shall be between 1.5 mm and 5 mm wide and between 3 mm and 5 mm deep, spaced 12 mm to 20 mm on centers. Tining shall be discontinued 300 mm from the curb line on bridge decks. The area adjacent to the curbs shall be given a light broom finish longitudinally. As an alternative, tining may be achieved using an approved machine designed specifically for tining or grooving concrete pavements.

10.12.2.4. Surface Testing and Correction

After the concrete has hardened, the Engineer will inspect finished deck roadway surfaces that will not be overlain with a wearing surface. Any variations in the surface which exceed 3 mm from a 3 m straightedge will be marked. The Contractor shall correct such irregularities by the use of concrete planning or grooving equipment which produces a textured surface equal in roughness to the surrounding unground concrete without shattering or otherwise damaging the remaining concrete.

10.12.3. Pedestrian Walkway Surface Finish

After the concrete for sidewalks and decks of pedestrian structures has been deposited in place, it shall be consolidated and the surface shall be struck off by means of a strike board and floated with wooden or cork float. If directed, the surface shall then be lightly broomed in a transverse direction. An edging tool shall be used on edges and expansion joints. The surface shall not vary more than 3 mm under a 1.5 m
straightedge. The surface shall have a granular or matte texture that will not be slippery when wet.

Sidewalk surfaces shall be laid out in blocks with an approved grooving tool as specified in the contract documents or as directed by the Engineer.

10.12.4. Trowelled and Brushed Finish

Surfaces that are specified in the contract documents to be troweled shall first be finished as specified under Article 10.12.1 "General" Then, after the concrete is partially set, the surface shall be finished to a smooth surface by troweling with a steel trowel until a slick surface free of bleed water is produced. The surface shall then be brushed with a fine brush using parallel strokes.

10.12.5. Surface under Bearings

When metallic masonry plates are to be placed directly on the concrete or on filler material less than 3 mm thick, the surface shall first be finished with a float finish. After the concrete has set, the area which will be in contact with the masonry plate shall be ground as necessary to provide full and even bearing. When such plates are to be set on filler material between 3 mm and 12 mm thick, the concrete surface shall be steel trowel finished without brushing and the flatness of the finished surface shall not vary from a straightedge laid on the surface in any direction within the limits of the masonry plate by more than 1.5 mm. Surfaces which fail to conform to the required flatness shall be ground until acceptable.

Surfaces under elastomeric bearings and under metallic masonry plates which are supported on mortar or filler pads 12 mm or greater in thickness shall be finished by wood floating to a flat and even surface free of ridges.

10.13. Curing Concrete

10.13.1. General

All newly placed concrete shall be cured so as to prevent loss of water by use of one or more of the methods specified herein. Except for Class A(HPC) concrete, curing shall commence immediately after the free water has left the surface and finishing operations are completed. For Class A (HPC) concrete, water curing shall commence immediately after finishing operations are complete. If the surface of the concrete begins to dry before the selected cure method can be applied, the surface of the concrete shall be kept moist by a fog spray applied so as not to damage the surface.

Curing by other than waterproof cover, steam, or radiant-heat methods with precast concrete shall continue uninterrupted for seven days except for when pozzolans in excess of ten percent, by weight, of the portland cement are used in the mix. When such pozzolans are used, the curing period shall be ten days. For other than top slabs of structures serving as finished pavements and Class A(HPC) concrete, the above curing periods may be reduced and curing terminated when test cylinders cured under the same conditions as the structure indicate that concrete strengths of at least seventy percent (70%) of that specified have been reached.

When deemed necessary by the Engineer during periods of hot weather, water shall be applied to concrete surfaces being cured by the liquid membrane method or by the forms-in-place method, until the Engineer determines that a cooling effect is no longer required. Such application of water will be paid for as extra work.
10.13.2. MATERIALS

10.13.2.1. Water
Water shall conform to the requirements of Article 10.4.4, "Water".

10.13.2.2. Liquid Membranes
Liquid membrane-forming compounds for curing concrete shall conform to the requirements of AASHTO M 148 (ASTM C 309).

10.13.2.3. Water Proof Sheet Materials
Waterproof paper, polyethylene film, and white burlap polyethylene sheet shall conform to the requirements of AASHTO M 171 (ASTM C 171).

10.13.2.4. Methods

10.13.2.5. Forms-In-Place Method
Formed surfaces of concrete may be cured by retaining the forms in place without loosening for the required time.

10.13.2.6. Water Method
Concrete surface shall be kept continuously wet by Ponding, spraying, or covering with materials that are kept continuously and thoroughly wet. Such materials may consist of cotton mats, multiple layers of burlap, or other approved materials that do not discolor or otherwise damage the concrete.

10.13.2.7. Liquid Membrane Curing Compound Method
The liquid membrane method shall not be used on surfaces where a rubbed finish is required or on surfaces of construction joints unless it is removed by sand blasting prior to placement of concrete against the joint. Type 2, white pigmented, liquid membranes may be used only on the surfaces of bridge decks, on surfaces that will not be exposed to view in the completed work, or on surfaces where their use has been approved by the Engineer.

When membrane curing is used, the exposed concrete shall be thoroughly sealed immediately after the free water has left the surface. Formed surfaces shall be sealed immediately after the forms are removed and necessary finishing has been done. The solution shall be applied by power-operated atomizing spray equipment in one or two separate applications. Hand-operated sprayers may be used for coating small areas. Membrane solutions containing pigments shall be thoroughly mixed prior to use and agitated during application. If the solution is applied in two increments, the second application shall follow the first application within 30 min. Satisfactory equipment shall be provided, together with means to properly control and assure the direct application of the curing solution on the concrete surface so as to result in a uniform coverage at the rate of 0.27 liter/m².

If rain falls on the newly coated concrete before the film has dried sufficiently to resist damage, or if the film is damaged in any other manner during the curing period, a new coat of the solution shall be applied to the affected portions equal in curing value to that specified above.
10.13.2.8. **Waterproof Cover Method**

This method shall consist of covering the surface with a waterproof sheet material so as to prevent moisture loss from the concrete. This method may be used only when the covering can be secured adequately to prevent moisture loss.

The concrete shall be wet at the time the cover is installed. The sheets shall be of the widest practicable width and adjacent sheets shall overlap a minimum of 150 mm and shall be tightly sealed with pressure sensitive tape, mastic, glue, or other approved methods to form a complete waterproof cover of the entire concrete surface. The waterproof sheet shall be secured so that wind will not displace it. Should any portion of the sheets be broken or damaged before expiration of the curing period, the broken or damaged portions shall be immediately repaired. Sections that have lost their waterproof qualities shall not be used.

10.13.2.9. **Steam or Radiant-Heat Curing Method**

This method may be used only for precast concrete members manufactured in established plants.

Steam curing or radiant-heat curing shall be done under a suitable enclosure to contain the live steam or the heat. Steam shall be low-pressure and saturated. Temperature recording devices shall be employed as necessary to verify that temperatures are uniform throughout the enclosure and within the limits specified in the contract documents.

The initial application of the steam or of the heat shall not occur prior to initial set of the concrete except to maintain the temperature within the curing chamber above the specified minimum temperature. The time of initial set may be determined by the Standard Method of Test for Time of Setting of Concrete Mixtures by Penetration Resistance, AASHTO T 197 (ASTM C 403/C 403M).

During the waiting period, the temperature within the curing chamber shall not be less than ten degrees Celsius (10°C) and live steam or radiant heat may be used to maintain the curing chamber at the proper minimum temperature. During this period the concrete shall be kept wet.

Application of live steam shall not be directed on the concrete or on the forms so as to cause localized high temperatures. During the initial application of live steam or of radiant heat, the temperature within the concrete shall increase at an average rate not exceeding twenty-two degree Celsius (22°C) per hour until the curing temperature is reached. The maximum curing temperature within the concrete shall not exceed seventy-one degree Celsius (71°C). The maximum temperature shall be held until the concrete has reached the desired strength. In discontinuing the steam application, the concrete temperature shall not decrease at a rate to exceed twenty-two degree Celsius (22°C) per hour until a temperature eleven degree Celsius (11°C) above the temperature of the air to which the concrete will be exposed has been reached.

Radiant heat may be applied by means of pipes circulating steam, hot oil, or hot water, or by electric heating elements. Radiant-heat curing shall be done under a suitable enclosure to contain the heat, and moisture loss shall be minimized by covering all exposed concrete surfaces with a plastic sheeting or by applying an approved liquid membrane curing compound to all exposed concrete surfaces. Top surfaces of concrete members to be used in composite construction shall be clear of residue of the membrane curing compound so as not to reduce bond below design limits. Surfaces of concrete members to which other materials will be bonded in the finished structure
shall be clear of residue of the membrane curing compound so as not to reduce bond below design limits.

For Prestressed members, the transfer of the stressing force to the concrete shall be accomplished immediately after the steam curing or heat-curing has been discontinued.

10.13.3. Bridge Decks

The top surfaces of bridge decks shall be cured by a combination of the liquid membrane curing compound method and the water method. The liquid membrane shall be Type 2, white pigmented, and shall be applied from finishing bridges progressively and immediately after finishing operations are complete on each portion of the deck. The water cure shall be applied not later than 4 h after completion of deck finishing or, for portions of the decks on which finishing is completed.

When Class A(HPC) concrete is used in bridge decks, water cure shall be applied immediately after the finishing of any portion of the deck is complete and shall remain in place for a minimum period of seven days irrespective of concrete strength. If conditions prevent immediate application of the water cure, an evaporation retardant shall be applied immediately after completion of finishing or fogging shall be used to maintain a high relative humidity above the concrete to prevent drying of the concrete surface. Following the water cure period, liquid membrane curing compound may be applied to extend the curing period.

10.14. Finishing Formed Concrete Surfaces


All concrete shall be given a Class 1, Ordinary Surface Finish and, in addition, if further finishing is required, such other type of finish as is specified.

Surface finishes for formed concrete surfaces shall be classified as follows:

Class 1-Ordinary Surface Finish
Class 2-Rubbed Finish
Class 3-Tooled Finish
Class 4-Sandblast Finish
Class 5-Wire Brush or Scrubbed Finish

If not otherwise specified in the contract documents, exposed surfaces except the soffits of superstructures and the interior faces and bottoms of concrete girders shall also be given a Class 2, Rubbed Finish.

Class 3, 4, or 5 type surface finishes shall be applied only where specified in the contract documents.

10.14.2. Class 1 –Ordinary Surface Finish (2)

Immediately following the removal of forms, fins and irregular projections shall be removed from all surfaces that are to be exposed or waterproofed. Bulges and offsets in such surfaces shall be removed with carborundum stones or discs.

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1 The liquid membrane, Type 2, white pigmented is as defined in AASHTO M 148 (ASTM C 309).
Localized, poorly bonded rock pockets or honey combed concrete shall be removed and replaced with sound concrete or packed mortar as specified in Article 10.16, "Mortar and Grout". If, in the opinion of the Engineer, rock pockets are of such an extent or character as to affect the strength of the structure materially or to endanger the life of the steel reinforcement, the Engineer may declare the concrete defective and require the removal and replacement of the portions of the structure affected.

On all surfaces, the cavities produced by form ties and all other holes, broken corners or edges, and other defects shall be thoroughly cleaned and, after having been thoroughly saturated with water, shall be carefully pointed and trued with a mortar conforming to Article 10.16. For exposed surfaces, white cement shall be added to the mortar in an amount sufficient to result in a patch that, when dry, matches the surrounding concrete. Mortar used in pointing shall be not more than 1h old. The concrete shall then be rubbed if required or the cure continued as specified in Article 10.12, "Finishing Plastic Concrete." Construction and expansion joints in the completed work shall be left carefully tooled and free of mortar and concrete. The joint filler shall be left exposed for its full length with clean and true edges.

The resulting surfaces shall be true and uniform. Repaired surfaces, the appearance of which is not satisfactory, shall be "rubbed" as specified in Article 10.14.3, "Class 2-Rubbed Finish."

10.14.3. Class 2 –Rubbed Finish

After removal of forms, the rubbing of concrete shall be started as soon as its condition will permit. Immediately before starting this work, the concrete shall be thoroughly saturated with water. Sufficient time shall have elapsed before the wetting down to allow the mortar used in the pointing of rod holes and defects to thoroughly set. Surfaces to be finished shall be rubbed with a medium-coarse carborundum stone, using a small amount of mortar on its face. The mortar shall be composed of cement and fine sand, mixed in proportions used in the concrete being finished. Rubbing shall be continued until form marks, projections, and irregularities have been removed; voids have been filled; and a uniform surface has been obtained. The paste produced by this rubbing shall be left in place.

After other work that could affect the surface has been completed, the final finish shall be obtained by rubbing with a fine carborundum stone and water. This rubbing shall be continued until the entire surface is of a smooth texture and uniform color.

After the final rubbing is completed and the surface has dried, it shall be rubbed with burlap to remove loose powder and shall be left free from all unsound patches, paste, powder, and objectionable marks.

When metal forms, fiber forms, lined forms, or plywood forms in good condition are used, the requirement for a Class 2, Rubbed Finish may be waived by the Engineer when the uniformity of color and texture obtained with Class I finishing are essentially equal to that which could be attained with the application of a Class 2, Rubbed Finish. In such cases, grinding with powered disc grinders or light sandblasting with fine sand or other means approved by the Engineer may be utilized in conjunction with Class I finishing.

10.14.4. Class 3-Tooled Finish (2)

Finish of this character for panels and other like work may be secured by the use of a bush hammer, pick, crandall, or other approved tool. Air tools, preferably, shall be employed. No tooling shall be done until the concrete has set for at least 14 days and as
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much longer as may be necessary to prevent the aggregate particles from being "picked" out of the surface.

10.14.5. Class 4- Sandblasted Finish

The thoroughly cured concrete surface shall be sandblasted with hard, sharp sand to produce an even, fine-grained surface in which the mortar has been cut away, leaving the aggregate exposed.

10.14.6. Class 5- Wire-Brushed or Scrubbed Finish

Begin as soon as the forms are removed. Scrub the surface with stiff wire or fiber brushes using a solution of muriatic acid. Mix the solution in the proportion of 1 part acid to 4 parts water. Scrub until the cement film or surface is completely removed and the aggregate particles are exposed. Leave an evenly pebbled texture having the appearance of fine granite to coarse conglomerate depending upon the size and grading of aggregate. Wash the entire surface with water containing a small amount of ammonia.

10.15. Precast Concrete Members

10.15.1. General

Precast concrete members shall be constructed and placed in the work in conformance with the details specified in the contract documents.

If approved by the Engineer, precasting methods may be used for elements of the work which are otherwise indicated to be constructed by the cast-in place method. When such precasting is proposed, the Contractor shall submit working drawings showing construction joint details and any other information required by the Engineer.

10.15.2. Working Drawings

Whenever specified in the contract documents or requested by the Engineer, the Contractor shall provide working drawings for precast members. Such drawings shall include all details not provided in the contract documents for the construction and the erection of the members and shall be approved before any members are cast. Such approval shall not relieve the Contractor of any responsibility under the contract documents for the successful completion of the work.

10.15.3. Materials and Manufacture

The construction of precast concrete units shall follow the fabricator provided instructions and conforms to the following requirements:

Units shall be of the size and shape shown on the contract documents.

The reinforcing system shall be rigidly wired or fastened at all intersections and held to true position in the form by approved devices.

Units shall be cast on level, tight platforms that will not settle during the casting or curing. Forms shall conform to the general requirements of this Section for concrete form work. The casting location shall be accessible for vibrating and consolidation of the concrete. Under normal curing methods, side forms may be removed at any time after the concrete has taken its initial set (not less than four hours after casting of the concrete); however, the entire unit shall not be subjected to any handling stress until the
concrete has reached a strength of 20 MPa or a specified strength given in the contract documents.

Mixing and placing of concrete shall conform to the preceding requirements of this Section. Piling shall be cast in a horizontal position. Casting in tiers will not be permitted. Special care shall be exercised to vibrate and consolidate the concrete around the reinforcement and along against the forms. Concrete shall be placed continuously in each unit with special care being exercised to avoid horizontal or diagonal cleavage planes. All reinforcement shall be accurately placed and rigidly secured at the location shown by the contract documents or approved drawings and special care shall be exercised that the reinforcement is properly imbedded in the concrete in the completed unit in accordance with the position indicated on the contract documents.

10.15.4. Curing
After casting, all exposed concrete shall be protected by wet burlap or other approved material to prevent excessive loss of moisture during the initial set period. After the concrete has obtained its initial set (not less than four hours after casting), the side forms may be removed and the curing continued by one of the following methods. As an exception to the following curing methods, when a compressive strength of 30 MPa is obtained no further curing will be required. All strength determinations will be made by concrete cylinder tests.

10.15.4.1. Standard Curing Method
After removal of the side forms, the units shall remain on the pallets and not moved for a minimum period of three days, during which they shall be kept covered with saturated burlap, double thickness, or tarpaulin. If the unit has not reached strength of 20 MPa at the end of this minimum three day period, curing shall be continued for a period of seven additional days by use of membrane curing compound, covering with polyethylene sheeting, immersion in water, or by covering with a heavy layer of sand which is kept wet. Anytime after the first three days if the concrete reaches 20 MPa strength, curing may be discontinued and the units moved.

10.15.4.2. Steam Curing Method
After precast concrete has obtained its initial set, steam shall be applied in such a manner as to raise the temperature of the air surrounding the units at a rate not to exceed five degrees Celsius (5°C) per hour to a temperature not to exceed seventy-one degree Celsius (71°C). This raised temperature shall be maintained for a period of 24 hours; however, if a compressive strength of 20 MPa has not been obtained at the end of 24 hours, the steam curing shall be continued until the required strength is obtained. If a compressive strength of 20 MPa is obtained before the end of the 24 hours noted, the steam curing procedure may be stopped if the units are covered with polyethylene sheeting for an additional 24 hour period to compensate for the shorter period of steaming.

The steam curing of prestressed concrete items shall be as outlined in the contract documents.

10.15.5. Storage and Handling
Extreme care shall be exercised in handling and moving precast prestressed concrete members. Precast girders shall be transported in an upright position and the
directions of the reactions with respect to the member shall be as in the final position. Support points during transportation and storage should be located within 750 mm of their final position; otherwise, their location shall be shown on the shop drawings.

Prestressed concrete members shall not be shipped until tests on concrete cylinders, manufactured of the same concrete and cured under the same conditions as the girders, indicate that the concrete of the particular member has attained a compressive strength equal to the specified design compressive strength of the concrete in the member.

Care shall be taken during storage, hoisting, and handling of the precast units to prevent cracking or damage. Units damaged by improper storage or handling shall be replaced at the Contractor’s expense.

10.15.6. Erection

The Contractor shall be responsible for the structural integrity of precast members during all stages of construction. Lifting devices shall be used in a manner that does not cause damaging, bending, or torsional forces. After a member has been erected and until it is secured to the structure, temporary braces shall be provided as necessary to resist wind or other loads. If accidental loading is imparted on the precast member, an evaluation of the accidental loading effects must be prepared by the contractor and shared with the Engineer to insure that the member has not been damaged. The Engineer in turn has the right to reject the element if the analysis is not conclusive.

Precast deck form panels shall be erected and placed so that the fit of mating surfaces shall be such that excessive grout leakage will not occur. If such fit is not provided, joints shall be dry-packed or sealed with an acceptable caulking compound prior to placing the cast-in-place concrete. End panels for skewed structures may be sawed to fit the skew.

10.15.7. Epoxy-Bonding Agents for Precast Segmental Box Girders

10.15.7.1. Materials

Epoxy-bonding agents for match-cast joints shall be thermosetting 100 percent solid compositions that do not contain solvent or any non-reactive organic ingredient except for pigments required for coloring. Epoxy bonding agents shall be of two components, a resin and a hardener. The two components shall be distinctly pigmented, so that mixing produces a third color similar to the concrete in the segments to be joined, and shall be packaged in proportioned, labeled, ready-to-use containers.

Epoxy-bonding agents shall be formulated to provide application temperature ranges that will permit erection of match-cast segments at substrate temperatures from four degree Celsius (4°C) to forty-six degree Celsius (46°C). If two surfaces to be bonded have different substrate temperatures, the adhesive applicable at the lower temperature shall be used.

Epoxy-bonding agents shall be insensitive to damp conditions during application and, after curing, shall exhibit high bonding strength to cured concrete, good water resistivity, low creep characteristics, and tensile strength greater than the concrete. In addition, the epoxy-bonding agents shall function as a lubricant during the joining of the match-cast segments, as a filler to accurately match the surface of the segments being joined, and as a durable, watertight bond at the joint. If a substantive portion of the epoxy is exposed to light, and to prevent epoxy from degrading Ultra Violet (UV) rays, special protection to the exposed surfaces shall be used.
Epoxy-bonding agents shall be tested to determine their workability, gel time, open
time, bond and compression strength, shear, and working temperature range. The
frequency of the tests shall be as stated in the contract documents.

The Contractor shall furnish the Engineer with samples of the material for quality
assurance testing and a certification from a reputable independent laboratory indicating
that the material has passed the required tests.

Specific properties of epoxy and the test procedures to be used to measure these
properties shall be as described in the following Sub-articles.

1. Test 1-Sag Flow of Mixed Epoxy-Bonding Agent
   Testing Method: No testing is required. Specification: Mixed epoxy-bonding agent
   must be an AASHTO M 235M/M 235 Type VI, Grade 3 (non-sagging) consistency at
   the designated application temperature class for the bonding agents used.

2. Test 2-Gel Time of Mixed Epoxy-Bonding Agent
   Gel time is the period of time the mixing bonding agent remains workable in the
   mixing container during which it must be applied to the mach-cast joint surfaces.
   Testing Method: ASTM D 2471 (except that one liter and four liters quantities shall
   be tested).
   Specification: 30 min minimum on one liter and four liters quantities at the
   maximum temperature of the designated application temperature range. (Note: Gel time
   is not to be confused with open time specified in Test 3).

3. Test 3-Open Time of Bonding Agent
   Open time of bonding agent is the time period of workability of the epoxy–bonding
   agent for the erection and post tensioning operations.
   Testing Method: open time is determined using test specimens as detailed in
   Article 10.15.7.1.4. "Test 4- Three-Points Tensile Bending Test". The epoxy-bonding
   agent, at the highest specified application temperature, is mixed together and applied as
   instructed in Test 4 to the concrete prisms, which shall also be at the highest specified
   application temperature. The adhesive coated prisms shall be maintained for 60 min at
   the highest specified application temperature with the adhesive coated surface or
   surfaces exposed and uncovered before joining together. The assembled prisms are then
   cured and tested as instructed in Test 4.
   The epoxy-bonding agent shall be deemed acceptable for the specified application
   temperature only when essentially total fracturing of concrete paste and aggregate
   occurs with no evidence of adhesive failure.
   Construction situations may sometimes require application of the epoxy-bonding
   agent to the precast section prior to erecting, positioning, and assembling. This
   operation may require epoxy-bonding agents having prolonged open time. In general,
   where the erection conditions are such that the sections to be bonded are prepositioned
   prior to epoxy application, the epoxy-bonding agent shall have a minimum open time
   of 60 min within the temperature range specified for its application.

4. Test 4-Three-Point Tensile Bending Test
   Testing Method: AASHTO T 126 (ASTM C 192) 150×150×225 mm concrete
   prisms of 40 MPa compressive strength at 28 days shall be sand-blasted on one.
   150×150 mm side to remove mold release agent, laitance, etc, and shall be submerged
in clean water at the lower temperature of the specified application temperature range for 72 h. Immediately on removing the concrete prisms from the water, the sandblasted surfaces shall be air-dried for 1 h at the same temperature and fifty percent (50%) relative humidity and each shall be coated with approximately a 1.5 mm layer of the mixed bonding agent. The adhesive-coated faces of two prisms shall then be placed together and held with a clamping force normal to the bonded interface of 0.35 MPa. The assembly shall then be wrapped in a damp cloth that is kept wet during the curing period of 24 h at the lower temperature of the specified application temperature range.

After 24 h curing at the lower temperature of the application temperature range specified for the epoxy bonding agent, the bonded specimen shall be unwrapped, removed from the clamping assembly, and immediately tested. The test shall be conducted using the standard AASHTO T 97 (ASTM C 78). Test for flexural strength with third-point loading and the standard MR unit. At the same time the two prisms are prepared and cured, a companion test beam shall be prepared of the same concrete, cured for the same period, and tested following AASHTO T 97 (ASTM C 78).

Specification: The epoxy-bonding agent is acceptable if the load on the prisms at failure is greater than ninety percent (90%) of the load on the reference test beam at failure.

5. Test 5-Compression Strength of Cured Epoxy-Bonding Agent
   Specification: Compressive strength at twenty-five degree Celsius (25°C) shall be a minimum of 14 MPa after 24 h of curing at the minimum temperature of the designated application temperature range and 40 MPa at 48 h.

6. Test 6-Temperature Deflection of Epoxy-Bonding Agent
   Specification: A minimum deflection temperature of fifty degree Celsius (50°C) at fiber stress loading of 1.8 MPa is required on test specimens cured seven days at twenty-five degree Celsius (25°C).

7. Test 7-Compression and Strength of Cured Epoxy-Bonding Agent
   Testing Method: A test specimen of concrete is prepared in a standard 150×300 mm cylinder mold to have a height at midpoint of 150 mm and an upper surface with a 30° slope from the vertical. The upper and lower portions of the specimen with the slant surfaces may be formed through the use of an elliptical insert or by sawing a full-sized 150×300 mm cylinder. If desired, 75×50 mm or 100×200 mm specimens may be used. After the specimens have been moist cured for 14 days, the slant surfaces shall be prepared by light sandblasting, stoning, or acid etching, then by washing and drying the surfaces, and finally by coating one of the surfaces with a 0.25 mm thickness of the epoxy-bonding agent under test. The specimens shall then be pressed together and held in position for 24 h. The assembly shall then be wrapped in a damp cloth that shall be kept wet during an additional curing period of 24 h at the minimum temperature of the designated application temperature range. The specimen shall then be tested at twenty-five degree Celsius (25°C) following AASHTO T 22 (ASTM C 39/C 39M) procedures. At the same time as the slant cylinder specimens are made and cured, a companion standard test cylinder of the same concrete shall be made, cured for the same period, and tested following AASHTO T 22 (ASTM C 39/C 39M).
Specification: The epoxy-bonding agent is acceptable for the designated application temperature range if the load on the slant cylinder specimen is greater than ninety percent (90%) of the load on the companion cylinder.

10.15.7.2. Mixing and Installation of Epoxy

As general instructions contained herein cannot cover all situations, specific recommendations and instructions shall be obtained in each case from the Engineer in charge.

Instructions furnished by the supplier for the safe storage, mixing, and handling of the epoxy-bonding agent shall be followed. The epoxy shall be thoroughly mixed until it is of uniform color. Use of a proper-sized mechanical mixer operating at no more than 600 revolutions per minute shall be required. Contents of damaged or previously opened containers shall not be used.

Surfaces to which the epoxy material is to be applied shall be at least four degree Celsius (4°C) and shall be free from oil, laitance, form release agent, or any other material that would prevent the epoxy from bonding to the concrete surface. All laitance and other contaminants shall be removed by light sandblasting or by high pressure water blasting with a minimum pressure of 34 MPa. Wet surfaces shall be dried before applying epoxy-bonding agents. The surface shall be at least the equivalent of saturated surface dry (no visible water).

Mixing shall not start until the segment is prepared for installation. Application of the mixed epoxy-bonding agent shall be according to the Manufacturer's instructions using trowel, rubber glove, or brush on one or both surfaces to be joined. The coating shall be smooth and uniform in thickness and shall cover the entire surface with a minimum thickness of 1.5 mm applied on both surfaces. A discernible bead line shall be observed on all exposed contact areas after temporary post-tensioning. Erection operations shall be coordinated and conducted so as to complete the operations of applying the epoxy-bonding agent to the segments, erection, assembling, and temporary post tensioning of the newly joined segment within seventy percent (70%) of the open time period of the bonding agent.

The epoxy material shall be applied to all surfaces to be joined within the first half of the gel time, as shown on the containers. The segments shall be joined within 45 min after application of the first epoxy material placed and a minimum average temporary prestress of 0.3 MPa over the cross-section should be applied within seventy percent (70%) of the open time of the epoxy material. At no point of the cross-section shall the temporary prestress be less than 0.2 MPa.

The joint shall be checked immediately after erection to verify uniform joint width and proper fit. Excess epoxy from the joint shall be removed where accessible. All tendon ducts shall be swabbed immediately after stressing, while the epoxy is still in the non-gelled condition, to remove or smooth out any epoxy in the conduit and to seal any pockets or air bubble holes that have formed at the joint.

If the jointing is not completed within seventy percent (70%) of the open time, the operation shall be terminated and the epoxy-bonding agent shall be completely removed from the surfaces. The surfaces must be prepared again and fresh epoxy shall be applied to the surface before resuming jointing operations.
10.16. Mortar and Grout

10.16.1. General
This work consists of the making and placing of mortar and grout for use in concrete structures other than in prestressing ducts. Such uses include mortar for filling under masonry plates and for filling keyways between precast members where shown in the contract documents, mortar used to fill voids and repair surface defects, grout used to fill sleeves for anchor bolts, and mortar and grout for other such uses where required or approved.

10.16.2. Materials and Mixing
Materials for mortar and grout shall conform to the requirements of Article 3192H "Materials". The grading of sand for use in grout or for use in mortar when the width or depth of the void to be filled is less than 20 mm shall be modified so that all material passes the No.8 (2.36 mm) sieve.

Unless otherwise specified in the contract documents or ordered by the Engineer, the proportion of cement to sand for mortar shall be one to two and for grout shall be one to one. Proportioning shall be by loose volume.

When non-shrink mortar or grout is specified, either a non-shrink admixture or an expansive hydraulic cement conforming to ASTM C 845 of a type approved by the Engineer, shall be used.

Only sufficient water shall be used to permit placing and packing. For mortar, only enough water shall be used so that the mortar will form a ball when squeezed gently in the hand.

Mixing shall be done by either hand methods or with rotating paddle-type mixing machines and shall be continued until all ingredients are thoroughly mixed. Once mixed, mortar or grout shall not be retempered by the addition of water and shall be placed within 1h.

10.16.3. Placing and Curing
Concrete areas to be in contact with the mortar or grout shall be cleaned of all loose or foreign material that would in any way prevent bond, and the concrete surfaces shall be flushed with water and allowed to dry to a surface dry condition immediately prior to placing the mortar or grout.

The mortar or grout shall completely fill and shall be tightly packed into recesses and holes, on surfaces, under structural members, and at other locations specified. After placing, all surfaces of mortar or grout shall be cured by the water method as provided in Article 3193H "Curing Concrete", for a period of not less than three days.

Keyways, spaces between structural members, holes, spaces under structural members, and other locations where mortar could escape shall be mortar-tight before placing mortar.

No load shall be allowed on mortar that has been in place less than 72 h unless otherwise permitted by the Engineer.

All improperly cured or otherwise defective mortar or grout shall be removed and replaced by the Contractor at the Contractor's expense.
10.17. Application of Loads

10.17.1. General

Loads shall not be applied to concrete structures until the concrete has attained sufficient strength and, when applicable, sufficient prestressing has been completed, so that damage will not occur.

10.17.2. Earth Loads

Whenever possible, the sequence of placing backfill around structures shall be such that overturning or sliding forces are minimized. When the placement of backfill will cause flexural stresses in the concrete, and unless otherwise permitted by the Engineer, the placement shall not begin until the concrete has reached not less than eighty percent (80%) of its specified strength.

10.17.3. Construction Loads

Light materials and equipment may be carried on bridge decks only after the concrete has been in place at least 24 h, providing curing is not interfered with and the surface texture is not damaged. Vehicles needed for construction activities and having a mass between 450 kg and 1800 kg, and comparable materials and equipment loads, shall be allowed on any span only after the last placed deck concrete has attained a compressive strength of at least 20 MPa. Loads in excess of the above shall not be carried on bridge decks until the deck concrete has reached its specified strength. In addition, for post-tensioned structures, vehicles weighing over 2000 kg, and comparable materials and equipment loads, shall not be allowed on any span until the prestressing steel for that span has been tensioned.

Precast concrete or steel girders shall not be placed on substructure elements until the substructure concrete has attained seventy percent (70%) of its specified strength.

Otherwise, loads imposed on existing, new, or partially completed portions of structures due to construction operations shall not exceed the load carrying capacity of the structure, or portion of structure, as determined by the Strength II Load Combination in Table 3.1 of the (MA-100-D-V1/2). The compressive strength of concrete ($f'_{c}$) to be used in computing the load-carrying capacity shall be the smaller of the actual compressive strength at the time of loading or the specified compressive strength of the concrete.

10.17.4. Traffic Loads

Unless otherwise provided in the contract documents, traffic shall not be permitted on concrete decks until at least 14 days after the last placement of deck concrete and until such concrete has attained its specified strength.

10.18. Special Requirements for Segmental Bridges

10.18.1. Geometry Control

10.18.1.1. Deflection and Camber Data

The Contractor shall submit deflection and/or camber data for each stage of construction as required to construct the structure to its final grade. The procedure used shall account for the effect of the time-dependent prestress losses and creep which will occur during the construction phase. The data for the entire bridge, based on the
Contractor's proposed erection sequence, method, and schedule, shall be submitted to the Engineer for review prior to commencing construction of the pier shafts.

The camber of the structure will be monitored by the Contractor at each stage and corrective actions as approved by the Engineer shall be performed by the Contractor to assure proper erection of the structure to its final grade.

10.18.1.2. Geometry Control

The Contractor shall submit to the Engineer for approval a geometric control plan which shall indicate in detail how the survey is to be performed and the Contractor's proposed actions to assure proper erection of the structure to the final grade shown on the working drawings. The geometric control plan shall provide for regular monitoring of the superstructure deflections beginning with the addition of the first cantilever segments and concluding with the last cantilever segment. The plan shall include the adjusting procedure to be utilized, should the cantilever, as erected, deviate from the predicted alignment by more than 25 mm.

The Contractor shall check the elevations and alignment of the structure at every stage of construction and must maintain a record of all these checks and of all adjustments and corrections made. All surveying shall be performed at a time that will minimize the influence of temperature. Corrections by shimming shall be done only when approved by the Engineer.

For precast segmental construction using short line forming techniques, precision surveying systems shall be provided so that levels and horizontal alignment during precasting are measured to an accuracy of ±0.3 mm. For all other types of segmental construction and for erection of segmental bridges, surveying shall be provided to an accuracy of ±3 mm.

For precast segmental construction using match-cast segments, careful checks of both measurements and computations of geometry shall be made by the Contractor before moving segments from their casting position. Computed coordinates of all sections cast shall be completed before casting a new segment. In addition to the computed as-built casting curves for vertical and horizontal deflections, a cumulative twist curve shall be computed using the measured cross slopes of the individual units as a check on the extrapolated deflections. In computing set-up elevations in the match cast process, priority shall be given to correcting twist errors by proper counter-rotation. The segment in the match-cast position shall not be subjected to a stress inducing twist.

10.18.2. Tolerances

Unless otherwise specified, reinforcement shall be fabricated and placed within the tolerances specified herein (CRSI 1990).

- For specified effective depth, \( d \), and minimum clear concrete protection in flexural members, walls, and compression members, Table 10.13 illustrates the admissible tolerances.

<table>
<thead>
<tr>
<th>Effective depth ( d )</th>
<th>Tolerance on ( d )</th>
<th>Tolerance on Minimum Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 mm or less</td>
<td>±10 mm</td>
<td>-10 mm</td>
</tr>
<tr>
<td>More than 200 mm</td>
<td>±12 mm</td>
<td>-12 mm</td>
</tr>
</tbody>
</table>
But the tolerance on the clear distance to formed soffits shall be ±6 mm, and in no case shall the tolerance on cover exceed minimum one-third of the minimum cover stipulated on the structural drawings or in the specifications.

- For longitudinal location of bends and ends of bars: ±50 mm, except at discontinuous ends of members where tolerance shall be ±12 mm.
- As long as the total number of bars specified is maintained, a reasonable tolerance in spacing individual bars is ±25 mm, except where openings, inserts, embedded items, etc. might require some additional shifting of bars.

Embedded ducts for all types of segmental bridge construction shall be positioned to tolerances as specified in Section 12, "Prestressing", Article [12.5.3.2], "Placement of Ducts."

Tolerances for completed segments shall be taken as shown in Table 10.13. For bridges without an overlay, the flatness of the top slab shall be 3 mm in 3.0 m in the direction of traffic.

Dimensions from segment-to-segment shall be adjusted to compensate for any deviations within a single segment so that the overall alignment of the completed structure will conform to the dimensions shown on the contract documents.

When cantilever construction is used, the tolerances for the alignment of the opposing cantilevers in a span shall be stated in the contract documents. The forces up and down which can be placed on the end of the cantilever shall also be stated on the design drawings and shall consider the allowable tensile stresses for construction load combinations in Table 5.19 of the (MA-100-D-V1/2).

After erection, final post-tensioning, final corrections, and adjustments are complete and the structure has been placed on its permanent bearings, the superstructure shall conform to the grade and alignment shown on the contract documents, with due consideration of creep and superimposed dead-load deflections within tolerances as specified on the contract drawings.

**Table 10.14: Completed Segment Tolerance for Segmental Box Girder Bridge Construction**

<table>
<thead>
<tr>
<th>Length of Match-Cast Segment (Not Cumulative) (6.5 mm/m +25 mm max)</th>
<th>±6.5 mm /m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Cast-in-Place Segment</td>
<td>±12.5 mm but not greater than +50 mm per span</td>
</tr>
<tr>
<td>Web Thickness</td>
<td>±9.5 mm.</td>
</tr>
<tr>
<td>Depth of Bottom Slab</td>
<td>±9.5 mm.</td>
</tr>
<tr>
<td>Depth of Top Slab</td>
<td>±9.5 mm.</td>
</tr>
<tr>
<td>Overall Top Slab Width</td>
<td>±52 mm/m, ±25 mm. max.</td>
</tr>
<tr>
<td>Diaphragm Thickness</td>
<td>±12.5mm.</td>
</tr>
<tr>
<td>Grade of Form Edge and Soffit</td>
<td>±3 mm. in 3 m</td>
</tr>
<tr>
<td>Tendon Hole Location</td>
<td>±3 mm.</td>
</tr>
<tr>
<td>Position of Shear Keys</td>
<td>±6 mm.</td>
</tr>
</tbody>
</table>
10.18.3. Shop Drawings and Design Calculations for Construction Procedures

10.18.3.1. General

Sufficiently in advance of the start of superstructure field construction operations, so as to allow the Engineer not less than a 30 day review period, the Contractor shall submit according to a schedule complete details and information concerning the method, materials, equipment, and procedures the Contractor proposes to use in constructing that portion of the superstructure for which the information is furnished. This submittal shall include a step-by-step erection procedure.

More than one method or technique of erection may be permitted in the overall scope of work. Any subsequent deviation from the approved materials and/or details will not be permitted unless details are submitted by the Contractor and approved by the Engineer in advance of use.
The Contractor's submittals for approval shall include calculations, drawings and information outlined in Article 10.18.3.2, "Design Calculations for Construction Procedures" and Article 10.18.3.3, "Shop Drawings." Two sets of all required drawings and calculations shall be submitted and resubmitted if and as necessary until approved by the Engineer. The specified number of distribution copies shall be furnished after approval.

10.18.3.2. Design Calculations for Construction Procedures

Design calculations shall be submitted for falsework, erection devices, formwork, or other temporary construction which may be required and which will be subject to calculated stresses.

Design of the falsework or erection devices for all superstructure concrete shall be done under the direction of and sealed by a professional engineer. Calculations shall also be submitted to substantiate the system and method of stressing proposed by the Contractor. Such calculations shall include the required jacking force and elongation of tendons at time of tensioning, tendon stress level at stressing ends after seating, stresses in anchorage zones and distribution plates, stress-strain curves typical of the prestressing steel to be furnished, seating losses, temporary overstresses, and reinforcement required to resist anchor block stresses.

In addition to the above, computations shall be submitted for approval for the following:

- Computations of deflections and required camber due to dead loads, post-tensioning forces, creep, and shrinkage. A tabulation of deflections and camber dimensions shall be included on the shop drawings.
- Computations of jacking forces required at joints during temporary post-tensioning.

10.18.3.3. Shop Drawings

The Contractor shall submit detailed shop drawings for approval in accordance with the contract documents. The shop drawings shall include, but not necessarily be limited to, the following information:

- Fully and accurately dimensioned views showing the geometry of the segments including all projections, recesses, notches, openings, blockouts, and other pertinent details.
- Details of non-Prestressed steel reinforcing shall be clearly shown as to size, spacing, and location, including any special reinforcing required but not shown on the contract documents.
- Size and type of ducts for all post-tensioning tendons and their horizontal and vertical profiles shall be clearly detailed. Duct supports, grout tubes, vents, and drains shall be shown, including size, type, and locations.
- Details and locations of all other items to be embedded in the segments, such as inserts, Lifting devices, and post-tensioning hardware, shall be shown.
- Prestressing details including sizes and properties of tendons, anchorages, plates, assemblies, and stressing equipment, as well as details of the stressing procedure and stressing sequence, details and locations of all couplers, and additional reinforcement necessary to resist anchor block stresses.
- A table giving jacking sequence, jacking forces, and initial elongation of each tendon at each stage of erection for all post-tensioning.
- A table showing elevations and geometry to be used in positioning the forms for the next segment to be cast.
- Graphs, charts, or tables showing the theoretical location of each segment, as erected or placed, shall be furnished to the Engineer for use in checking the erection of the superstructure. Detailed procedures for making geometry corrections shall be described.
- Details of tie-down tendons and temporary and permanent bearing assemblies as required.
  Details of grouting equipment, grout mix design and method of mixing, and placing grout shall be provided

10.18.4. Forms

10.18.4.1. General

Shop drawings shall be submitted for forms and form travelers as required by the contract documents.

In addition to the requirements of the contract documents, the forms used to cast the concrete segments shall be capable of:
- Match-casting (for precast segmental construction).
- Producing the segments within the tolerances permitted.
- Accommodating blockouts, openings, and protrusions.
- Adjusting to changes in segment geometry as shown in the contract documents, or for correcting previous minor casting errors to prevent accumulations.
- Stripping without damage to the concrete.
- Providing a tight, leakproof joining to the previous segment.

The bulkhead must be capable of connecting the ducts in a manner to hold their position and prevent intrusion of grout.

Where sections of forms are to be joined on the exterior face of the segment, an offset in excess of 1.5 mm for flat surfaces and 3 mm for corners and bends will not be permitted. Offsets between adjacent matching faces of cast-in-place segments shall not exceed 6 mm.

Forms shall not be removed until the concrete has attained the release strength specified on the contract documents as evidenced by test cylinders made and cured in the same manner as the segment. Alternatively, maturity meters or instrument control cylinders may be used to evaluate the strength of the concrete in the segment. Care shall be exercised in removing the forms to prevent spalling and chipping of the concrete.

10.18.4.2. Forms for Precast Segmental Construction

All side, bottom, inside, and header forms for precast segmental construction shall be constructed of steel unless use of other materials is approved by the Engineer.

Forms shall be of sufficient thickness, with adequate external bracing and stiffeners, and shall be sufficiently anchored to withstand the forces due to placement and vibration of concrete. Internal bracing and holding devices in forms shall be limited to stay bolts in webs which can be removed from the concrete surface to permit patching following form removal. Joints shall be designed and maintained for mortar tightness.
The grade and alignment of forms shall be checked each time they are set and shall be maintained during the casting of concrete. Slab finish grade will be checked after the concrete is in place.

Metal forms shall be reasonably free from rust, grease, or other foreign materials. All forms shall be cleaned thoroughly prior to each casting operation. End headers shall be maintained to provide a smooth casting surface.

Wood forms may be used on the cast-in-place longitudinal and transverse closure strips.

The faces of all forms, other than end headers, shall be properly cleaned and treated with form oil or other bond breaking coating prior to placing concrete. Bond breaking material between segments and between segments and headers shall be provided in accordance with Article 10.18.6.3, "Separation of Match-Cast Segments". The oil or other materials used for this purpose shall be of a consistency and composition to facilitate form removal. Materials which appreciably stain or react with the concrete will not be constructed to facilitate segment removal without damage to the concrete.

10.18.5. Special Provision for Cast-In-Place Segmental Construction

10.18.5.1 General
The working drawings shall be prepared on the assumption that the superstructure will be constructed by a selected method of cast-in-place reinforced concrete segmental construction. Alternate construction methods may be permitted in accordance with the contract documents.

10.18.5.2 Forming System
In addition to the submittals required in Article 10.18.3, "Shop Drawings and Design Calculations for Construction Procedures", the following computations and working drawings shall be submitted for review by the Engineer for compliance with the contract documents:

- Details and computations shall be completed for the forms and form support system, including maximum loadings and stresses created in the completed segments due to equipment forms and concrete placement. Design of form support system shall include adequate allowances for impact loadings which may occur during concrete placement and advancement of forming system.
- Computations of deflection of the forming system during concrete placement.
- Details for temporary supports and tie-downs as needed to stabilize the cantilevers during construction.
- Detailed step-by-step procedure for concrete placement, stressing and advancing the form support system, and adjusting the system for calculated deflection.
- Detailed procedure for fixing the cantilever ends against changes in position or rotation of one cantilever relative to the other during and following placement of concrete for the closure between the cantilevers.
- In every stage of construction, the stability of the partially completed structure is a major concern. Therefore, the stability of partial structures should be evaluated to avoid any collapse due to various combination of loads (construction, wind loading, vibration from equipment, etc).
10.18.5.3. Superstructure Construction

This work shall be taken to consist of setting temporary bearings if applicable, casting segments in place, and setting the superstructure on permanent bearings.

The Contractor shall submit complete details and descriptions of the methods, arrangements, and equipment to the Engineer for approval before superstructure construction is started.

The construction method shall include casting of the segments, methods of the tie-down of superstructures during cantilever erection, and method of application of all temporary forces to be used for adjusting horizontal and vertical alignments and to place the structure on permanent bearings. This shall also include control methods to ensure the accuracy of alignment of the completed superstructure.

Work equipment shall be taken to include all machinery, devices, labor, and material which are to be used for erection but will not become a permanent part of the completed superstructure. Equipment must not be operated from or placed upon any part of erected superstructure at any stage of construction other than which specifically meets the requirement of total working load per segment, as allowed by the contract documents, and/or as approved by the Engineer. This includes the post-tensioning hardware; jointing, jacking, grouting equipment, and any other equipment whatsoever; and personnel and materials of any kind.

In addition to segment unbalanced loads which are permitted for the construction method, a \( (4.8 \times 10^4 \text{ MPa}) \) load is permissible. The load shall be taken to include personnel, miscellaneous equipment, and stored material. It shall be the Contractor's responsibility to ensure that this allowable load is not exceeded.

Stressing may be performed in accordance with the following schedule:

- Fifty percent (50%) of the post-tensioning force may be applied when field cured compression cylinders indicate the compressive strength of the segment concrete is 20 MPa, and 18 h have elapsed after completion of concrete placement.
- Form support system may be released and advanced when fifty percent (50%) of post-tensioning stress has been applied.
- Transverse stressing shall be staged as necessary to avoid exceeding the allowable stresses in the top slab.
- Tendons shall be fully tensioned prior to placement of concrete for the next segment, except the transverse tendon nearest the segment to be constructed. That tendon shall be stressed to fifty percent (50%), and then stressed the remainder when tendons in the new segment are stressed. The form support system shall be designed to avoid overstressing the top slab in the area of the partially stressed tendon.

Construction joints shall be limited to locations shown in the contract documents or as approved, in advance, by the Engineer. All construction joints shall be thoroughly cleaned of laitance and foreign material prior to placing concrete for the abutting section.

Surface of the segment joints shall be prepared in accordance with the contract documents immediately prior to placement of concrete for the next segment.

For placement of closure concrete between cantilevers, the cantilevers shall be fixed to prevent rotation or movement of one cantilever relative to the other. The system for locking the cantilevers and forming for the closure and the procedure for placing the concrete for the closure shall be such that the concrete after the initial set shall not be subjected to tension which could cause cracking.
The Contractor shall submit a construction schedule or check list showing chronological order of every phase and stage of erection and construction of the superstructure.

The Contractor shall prepare a table of elevations and alignments required at each stage of erection, as required by the contract documents, at the check points listed below, or an alternative at Contractor's option, and submit the same to the Engineer.
- One of the lowest corners at the top surface of any temporary bearing pads to be used as datum during erection and to establish a reference point with the actual elevations and alignment required of the permanently positioned superstructure.
- All four corners and centerline (at segment faces) of top slab of pier segments to establish grade and crown.
- Two points on the longitudinal centerline of each pier segment, one on each edge, to establish alignment.
- One point on the longitudinal centerline and at least one corner of each segment along every joint between cast-in-place segments to establish elevations and alignment at every stage of erection.

The temporary bearing pads, if applicable, at the piers shall be very carefully placed. The top surfaces of these pads shall have the correct elevations, alignments, and slopes as required by the contract documents and so established by the provisions above for temporary bearing pads. Shims may be used underneath the pads to accomplish accuracy. The Contractor shall also devise and provide measures to hold temporary bearing pads in position while the pier segment is being cast.

The Contractor shall check the elevations and alignment of the structure at every stage of construction in accordance with the geometry control plan submitted in accordance with the provisions of Article 10.18.1.2, "Geometry Control," and shall maintain a record of all these checks and of all adjustments and corrections made.

### 10.18.6. Special Provision for Precast Concrete Segmental Construction

#### 10.18.6.1. General

The superstructure shall be erected by the method designed and detailed in the contract documents or by an alternate method submitted by the Contractor. Alternate erection methods may be permitted when specified in the contract documents.

When required by the contract documents, the stressing system and all reinforcement and lifting details shall be successfully demonstrated on a segment designated in the contract documents prior to casting any permanent segments. The segment shall conform to the size and configuration required by the contract documents, including post-tensioning anchorage pockets, reinforcing steel, concrete, and conduits, including curvature and spacing. The tendons designated in the contract documents for this test shall be stressed to the forces shown. No additional payment shall be made for this test.

Casting bed and forms shall be structurally adequate to support the segments without settlement or distortion. The casting bed shall be designed for a method and the hardware needed to adjust and maintain grade and alignment. Details for hardware and adjustment procedures shall be included in the contract documents and specifications for the casting bed.

Grading of the soffit form and the top portion of each segment shall take into consideration the relative position of the member in the structure.
After the first segment of each unit is cast, all succeeding segments shall be cast against previously cast segments to ensure complete bearing and proper alignment on all mating surfaces.

The anchorage system shall permit tendons to be inserted in the member after erection of segments.

Tendon couplers shall be used only at locations specifically shown in the contract documents or approved by the Engineer. Not more than fifty percent (50%) of the tendons shall be coupled at any section. When temporary external tendons are required by the contract documents, the tendons and anchors shall be in a protective enclosure capable of protecting the tendons from damage by erection equipment and capable of confining a strand or bar tendon that breaks or otherwise releases tension rapidly during or after tensioning and anchorage. Protective enclosure proposals shall be submitted to the Engineer for approval.

Care shall be taken to ensure that deformations of match-cast segments due to thermal gradients caused by the heat of hydration of the new cast concrete do not exceed, at the time of initial set of the new concrete, 0.8 mm for a single segment or 20 mm cumulative for an entire span. These deformations shall be prevented by properly protecting both the match-cast and new cast segments in an isothermal enclosure or with curing blankets and plastic sheeting.

10.18.6.2. Fabrication

Reinforcing steel shall be fabricated and placed according to the contract documents. Any conflict or interference with the proper location of ducts and/or reinforcing, or block outs shall be promptly resolved and corrections made as directed by the Engineer. No reinforcing steel shall be cut and removed to permit proper alignment of stressing conduits. Any bar that cannot be fabricated to clear the post-tensioning duct shall be replaced by additional bars with adequate lap lengths and shall be submitted to the Engineer for approval.

All segments shall be marked on the inside with a unique identification at the time of form removal. This identification shall be used to identify each segment on shop contract documents, post-tensioning details and calculations, and any other document pertaining to the fabrication and erection of precast concrete segments.

Positive means of holding the conduit in its correct position shall be provided in all cases and shall be indicated on the working drawings submitted for approval. The conduit shall be supported at intervals as specified in Section 12, "Prestressing", "Placement of Ducts," or as shown in the contract documents, and shall be securely fastened to prevent movement during placement of concrete.

10.18.6.3. Separation of Match-Cast Segments

The Contractor shall provide equipment to be used for uniform separation of match-cast segments without damage. The method, as well as details of the equipment to be used for separating match-cast segments, shall be included in the shop contract documents. A bond breaking material shall be used on the web and flanges of the previously cast segment to facilitate separation of segments. The bond breaking material shall be used to break the bond of concrete between the face of previously cast segments and a newly cast segment, as well as the end headers, when required. The bond breaker shall consist of flax soap and talc, or other material approved by the Engineer. A demonstration shall be performed on a 600×1200 mm specimen, prior to the casting of segments, to prove the adequacy of the material. The material shall not be
injurious to the concrete and shall permit removal of a segment without pullouts caused by adhesion of the concrete.

10.18.6.4. Handling and Erection of Segments

The Contractor (Fabricator) shall be responsible for proper handling, lifting, storing, transporting, and erection of all segments so that they may be placed in the structure without damage.

Segments shall be maintained in an upright position at all times and shall be stored, lifted, and/or moved in a manner to prevent torsion and other undue stress. Members shall be lifted, hoisted, or stored with lifting devices approved on the shop contract documents or by other methods approved by the Engineer in writing.

Segments shall not be moved from the casting yard until all curing and strength requirements have been attained and shall be supported in a manner that will minimize warping.

A full-scale test of the lifting and temporary holding hardware shall be performed to demonstrate the adequacy of this equipment prior to beginning any erection of the segments.

10.18.7. Special Provisions for Incremental Launching

10.18.7.1. General

Structures built by the incremental launching method shall comply with the provisions of Article [10.18.3], "Shop Drawings and Design Calculations for Construction Procedures", and the additional provisions of the following article.

10.18.7.2. Casting of Segments

Construction of incrementally launched bridges should be based on a weekly cycle for the construction of each segment. When the bottom flange and webs, or portions of webs, of segments are cast first and the top flange afterward, the time between concrete placements shall not exceed three days.

10.18.7.3. Geometric Tolerances

The following tolerances shall not be exceeded in the region of the sliding surfaces:

- In the Forms:
  - Vertical deviations in longitudinal and transverse direction: ±0.8 mm
  - Horizontal deviation at the outside of webs: ±1.5 mm
- On the Launching Bearings:
  - Vertical: Longitudinally between piers: ±1.5 mm
  - Transversely between bearings: ±0.8 mm
  - Horizontal: Deviation of lateral guides: ±1.5 mm

10.18.7.4. Launching Force

The launching force shall be monitored continuously and checked against the theoretical value. A friction value between zero and four percent shall be maintained. The friction value of zero shall be considered in calculation of the force required to hold back a structure launched on a negative gradient.
10.18.7.5. Pier Monitoring

The deflection of the pier tops shall be continuously monitored. Monitoring devices which automatically switch off the launching equipment in case the permissible pier deflections are exceeded are recommended. Communication between each sliding bearing and the launching equipment shall be provided.

The correct level of all sliding bearings shall be checked at regular intervals. Shim plates shall be kept in stock for all sliding bearings in order to compensate for pier settlements, if any.

10.18.8. Defects and Breakage

Minor or nonstructural cracks or checks on the surface of the member which, as determined by the Engineer, do not extend to the plane of the nearest reinforcement will be acceptable unless they are numerous and extensive. Diagonal cracks which indicate damage from torsion, longitudinal cracks that follow stressing tendons, or any cracks which extend into the plane of the reinforcing steel and/or prestressed tendons shall be subject to a structural review prior to acceptance. If found acceptable, the cracks shall be repaired by "veeing" out 6 mm deep and wide and sealing with epoxy or shall be repaired by epoxy injection.

Minor breakage, spalling, or honeycombing not over 25 mm deep shall be repaired in accordance with an established repair procedure submitted to and approved by the Engineer prior to the start of segment fabrication. Major breakage or honeycomb in excess of that specified herein shall be subject to structural review. If found to be satisfactory, these areas shall be repaired as directed by the Engineer. Breakage, spalling, or honeycomb on any mating surface found to be acceptable shall be repaired and the concrete cured prior to casting the mating segment if such segment has not yet been cast.

10.19. Concrete for Minor Structures

10.19.1. Description

This work consists of constructing minor concrete structures such as pipe culvert headwalls, wing-walls and aprons, spillways, slope paving, sidewalks, curbs and other minor concrete structures in accordance with these specifications and in reasonable close conformity with the lines, grades, details and locations shown on the plans or established by the Engineer.

10.19.2. Materials

All minor concrete structure materials shall conform to the requirements contained in Article 10.4, "Materials" in these General Specifications.

10.19.3. Composition of Concrete for Minor Structure

Concrete for minor Structure shall conform to the requirements of Table 10.1. Before batching concrete, the Contractor shall submit the proposed concrete proportions for approval. As a minimum, the following shall be submitted:

1. Type and source(s) of all material proposed for use.
2. Material certification for all material proposed for use including cement.
3. Saturated surface dry weight of the fine and coarse aggregate per cubic meter of concrete.
4. Gradation of fine and coarse aggregate.
5. Weight of mixing water per cubic meter of concrete.
6. Weight of cement per cubic meter of concrete.
7. Maximum slump of plastic concrete in millimeters satisfying the requirements of Table 10.5.

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum cement content</td>
<td>310 kg/m³</td>
</tr>
<tr>
<td>Maximum W/C ratio</td>
<td>0.49</td>
</tr>
<tr>
<td>Maximum slump</td>
<td>100 mm</td>
</tr>
<tr>
<td>Size of coarse aggregate</td>
<td>Article 10.4.2.2 &quot;Coarse Aggregate&quot;</td>
</tr>
<tr>
<td>Minimum 28-day compressive strength</td>
<td>20 Mpa</td>
</tr>
</tbody>
</table>

Class B structural concrete complying with Table 10.1 in these Specifications will be acceptable as an approved mixture with appropriate certification.

The Contractor shall perform the preparatory work in accordance with Section 4, "Structure Excavation and Backfill," in these General Specifications. He shall design and construct forms that are free of bulge and warp and allow for removal without injuring the concrete. Reinforcing steel shall be placed according to the "Manual of Standard Practice" of the Concrete Reinforcing Steel Institute. When concrete contains a retarding admixture, fly ash, or other pozzolan replacement for cement, forms shall be designed for a lateral pressure equal to that exerted by a fluid having a mass of (2400 kg/m³).

Wood, metal, or other suitable material shall be used. Forms shall be kept clean and coated with form release agent or form oil before placing concrete.

10.19.4. Placing of Concrete

The forms and foundation shall be moistened immediately before placing concrete. The concrete shall be discharged within the time limit shown in Article 10.6.4, "Batching and Mixing of Concrete," in these Specifications.

Concrete shall be handled and placed to avoid segregation in accordance with Article 10.8, "Handling and Placing of Concrete" in these general Specifications. Aluminum pipe for transporting or placing concrete shall not be used. The intervals between delivery of batches for a single pour on a structure shall not exceed thirty (30) minutes.

Placement shall conform to the requirements of Article 10.7, "Protection of Concrete from Environmental Conditions" in these Specifications when there is a forecast of air temperatures below an atmospheric temperature of two degrees Celsius (2°C) or above twenty-five degrees Celsius (25°C).

Water shall not be supplied to plastic concrete finishes during finishing operations.
10.19.5. Curing of Concrete

Minor concrete shall be cured a minimum of seven (7) days. If high early strength cement is used, cure concrete a minimum of three (3) days. Curing shall be according to Article 10.13, “Curing Concrete” in these specifications.

10.19.6. Acceptance

Concrete for minor structures will be subject to acceptance or rejection by visual inspection and review of the load certification at the placement site. Retempering of concrete will not be permitted. The Engineer will take or supervise the taking of slump tests, test cylinders or cores for strength determination checks.

10.20. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and this section requirements. For work acceptance, Contractor shall apply quality control for concrete structure construction work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.

The Ministry shall apply quality assurance and verify the Contractor quality control procedures either through direct supervision or by carrying out neutrally quality assurance procedures using test on representative samples and in adequate numbers to judge about the quality level and accept or reject the executed works according to the principles detailed mentioned bellow in next paragraphs.

10.20.1. Quality Control

All materials and concrete works in construction the structures should be controlled according to the requirements of concrete production of the articles 10.4.1, 10.4.2, 10.4.3 and 10.4.4, all mixing materials process should be inspected to control and insure that all mixing percentage are correct in addition to the water/cement percentage are conforming the requirements of article 10.5 and the specification mentioned in Table 10.18. The allowable percentages of chemical and mineral admixtures mentioned in article 10.5.4, should be used in case if the contract documents include permission of using the admixture in concrete. Storage, measurements, mixture quantities and sampling of concrete production should be according to the section 10.6.

For work acceptance, compressive strength test should be done on concrete samples according to the frequency of testing and acceptance requirement mentioned in article 10.6.7.

Precautions shall be taken as needed to protect concrete from damage due to weather or other environmental conditions during placing and curing periods according to the article 10.7.

10.20.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of concrete mixing, production, handling and placing are conforming the required specification to get the required strength, through carrying out or ordering others to carry out under its supervision the tests that insure the quality of concrete. Also, Ministry has the right to insure the specified test results if there is any doubt in test result by asking the contractor to do required test on the concrete in the site.
10.21. Measurement and Payment

10.21.1. Measurement

Except for concrete in components of the work for which payment is made under other bid items, all concrete for structures shall be measured by either the cubic meter for each class of concrete included in the contract documents or by the unit for each type of precast concrete member listed in the contract documents.

When measured by the cubic meter, the quantity of concrete shall be computed from the dimensions shown in the contract documents or authorized in writing by the Engineer with the following exceptions:

- The quantity of concrete involved in fillets, scorings, and chamfers 645 mm² or less in cross-sectional area shall not be included or deducted.
- When there is a bid item for concrete to be used as a seal course in cofferdams, the quantity of such concrete to be paid for shall include the actual volume of concrete seal course in place, but in no case shall the total volume measured exceed the product of the area between vertical surfaces 300 mm outside the neat lines of the seal course as shown in the contract documents and the thickness of the seal course. The thickness of seal course to be paid for shall be the thickness specified in the contract documents or ordered in writing by the Engineer.

The number of precast concrete members of each type listed in the contract documents will be the number of acceptable members of each type furnished and installed in the work.

Expansion joint armor assemblies will be measured and paid for as provided for in Section 22, "Miscellaneous Metal".

Whenever an alternative or option is shown in the contract documents, the quantities of concrete shall be computed on the basis of the dimensions specified in the contract documents and no change in quantities measured for payment shall be made because of the use by the Contractor of such alternatives or options.

10.21.2. Payment

The cubic meters of concrete and the number of precast concrete members, as measured above for each type of class listed in the contract documents, shall be paid for the contract prices per cubic meter or the contract prices per each member.

Payment for concrete of the various classes and for precast concrete members of the various types shall be considered to be full compensation for the cost of furnishing all labor, materials, equipment, and incidentals; and for doing all the work involved in constructing the concrete work complete in place, as specified in the contract documents. Such payment shall be taken as to include full compensation for furnishing and placing expansion joint fillers, sealed joints, waterstops, drains, vents, miscellaneous metal devices, and the drilling of holes for dowels and the grouting of dowels in drilled holes, unless payment for such work is specified in the contract documents to be included in another bid item.

In addition, payment for precast concrete members shall be considered to be full compensation for the cost of all reinforcing steel, prestressing materials, and other items embedded in the member and for the erection of the members.

Payment will be made under one or more of the items in Table 10.16. The quality control requirements for concrete structures are shown in Table 10.17.
Table 10.16: Concrete Structures Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.3.1</td>
<td>Normal-Weight Concrete</td>
<td>Cubic Meter</td>
</tr>
<tr>
<td>10.3.2</td>
<td>Lightweight Concrete</td>
<td>Cubic Meter</td>
</tr>
<tr>
<td>10.11.1</td>
<td>Contraction Joints</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>10.11.2</td>
<td>Expansion Joints</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>10.12.2.1</td>
<td>Approach slab</td>
<td>Square Meter</td>
</tr>
<tr>
<td>10.12.2.2</td>
<td>Bridge deck overlay</td>
<td>Square Meter</td>
</tr>
<tr>
<td>10.15.1</td>
<td>Precast Concrete</td>
<td>Each</td>
</tr>
<tr>
<td>10.16.1</td>
<td>Mortar And Grout</td>
<td>Lump sum</td>
</tr>
<tr>
<td>10.19.1</td>
<td>Concrete for Minor Structures</td>
<td>Cubic Meter</td>
</tr>
</tbody>
</table>

Table 10.17: Quality Control Requirements For Concrete Structures

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation and Acceptance of Concrete</td>
<td>Frequency of testing (SBC)</td>
<td>Compression test</td>
<td>In situ</td>
<td>once for each 120 m³ or once for each 500 m²</td>
<td>Article 10.6.7</td>
</tr>
<tr>
<td></td>
<td>Surface testing and correction</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>All surface</td>
<td>Article 10.12.2.4</td>
</tr>
<tr>
<td>Segmental Bridges</td>
<td>Geometry control</td>
<td>Check the elevations and alignment</td>
<td>In situ</td>
<td>Each segment</td>
<td>Article 10.18.1.2</td>
</tr>
<tr>
<td>Class 1 – Ordinary Surface Finish</td>
<td>The resulting surfaces shall be true and uniform</td>
<td>Surveying</td>
<td>In situ</td>
<td>Once</td>
<td>Article 10.14.2</td>
</tr>
<tr>
<td>Class 2 – Rubbed Finish</td>
<td>Smooth texture and uniform color</td>
<td>Surveying</td>
<td>In situ</td>
<td>Once</td>
<td>Article 10.14.3</td>
</tr>
<tr>
<td>Class 3-Tooled Finish</td>
<td>No tooling shall be done until the concrete has set for at least 14 days</td>
<td>Number of days</td>
<td>In situ</td>
<td>Once</td>
<td>Article 10.14.4</td>
</tr>
<tr>
<td>Class 4-Sandblasted Finish</td>
<td>The resulting surface shall be fine-grained</td>
<td>Surveying</td>
<td>In situ</td>
<td>Once</td>
<td>Article 10.14.5</td>
</tr>
<tr>
<td>Class 5- Wire-Brushed or Scrubbed Finish</td>
<td>Scrub the surface with stiff wire or fiber brushes using a solution of muriatic acid</td>
<td>Surveying</td>
<td>In situ</td>
<td>Once</td>
<td>Article 10.14.6</td>
</tr>
<tr>
<td>ACCEPTANCE LIMIT</td>
<td>AASHTO DESIGNATION</td>
<td>ASTM DESIGNATION</td>
<td>TITLE</td>
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<tr>
<td>as specified</td>
<td>AASHTO M85</td>
<td>ASTM C 150</td>
<td>Standard Specification for Portland Cement</td>
<td></td>
<td></td>
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<tr>
<td>as specified</td>
<td>AASHTO M240</td>
<td>ASTM C 595</td>
<td>Standard Specification for Blended Hydraulic Cements</td>
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<tr>
<td>as specified</td>
<td></td>
<td>ASTM C 1157</td>
<td>Standard Performance Specification for Hydraulic Cement</td>
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<tr>
<td>as specified</td>
<td></td>
<td>ASTM C 845</td>
<td>Standard Specification for Expansive Hydraulic Cement</td>
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<tr>
<td>as specified</td>
<td>AASHTO M6</td>
<td>ASTM C897-05</td>
<td>Standard Specification for Fine aggregate for Portland cement concrete</td>
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<td>as specified</td>
<td>AASHTO M80</td>
<td>ASTM C33-07</td>
<td>Standard Specification for coarse aggregate for Portland cement concrete</td>
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<td>as specified</td>
<td>AASHTO M21</td>
<td>ASTM A709/A709M-08</td>
<td>Standard Specification for Structural Steel for Bridges</td>
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<td>as specified</td>
<td>AASHTO M195</td>
<td>ASTM C 330</td>
<td>Standard Specification for Lightweight Aggregates for Structural Concrete</td>
<td></td>
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<tr>
<td>as specified</td>
<td>AASHTO M295</td>
<td>ASTM C 618</td>
<td>Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete</td>
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<td></td>
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<tr>
<td>as specified</td>
<td>AASHTO M307</td>
<td>ASTM C 1240</td>
<td>Standard Specification for Silica Fume Used in Cementitious Mixtures</td>
<td></td>
<td></td>
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<tr>
<td>as specified</td>
<td>AASHTO M302</td>
<td>ASTM C 989</td>
<td>Standard Specification for Slag Cement for Use in Concrete and Mortars</td>
<td></td>
<td></td>
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<tr>
<td>as specified</td>
<td>AASHTO M194</td>
<td>ASTM C494 / C494M - 08a</td>
<td>Standard Specification for Chemical Admixtures for Concrete</td>
<td></td>
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<tr>
<td>as specified</td>
<td>AASHTO M154</td>
<td>ASTM C 260</td>
<td>Standard Specification for Air-Entraining Admixtures for Concrete</td>
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<td>ACCEPTANCE LIMIT</td>
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<td>ASTM DESIGNATION</td>
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<tr>
<td>the apparent air content &lt; 0.1%</td>
<td>AASHTO T152</td>
<td>ASTM C231 - 08c</td>
<td>Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method</td>
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<tr>
<td>percent air &lt;0.25%</td>
<td>AASHTO T196</td>
<td>ASTM C173 / C173M -08a</td>
<td>Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method</td>
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<tr>
<td>air content &lt; 0.1%</td>
<td>AASHTO T199</td>
<td></td>
<td>Air content of freshly mixed concrete by the chace idicator</td>
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<tr>
<td>≥ 90 % of strengths of similar specimens made with potable water</td>
<td></td>
<td>ASTM C 109</td>
<td>Standard Test Method for Compressive Strength of Hydraulic Cement Mortars Using 2.in. or [50.mm] Cube Specimens</td>
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<tr>
<td>as specified</td>
<td></td>
<td>ASTM C 94</td>
<td>Specification for Ready.Mixed Concrete</td>
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<tr>
<td>as specified</td>
<td></td>
<td>ASTM C 685</td>
<td>Specification for Concrete Made by Volumetric Batching and Continuous Mixing</td>
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<tr>
<td>as specified</td>
<td></td>
<td>ASTM C 192</td>
<td>Method of Making and Curing Concrete Test Specimens in the Laboratory</td>
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<tr>
<td>the Powers spacing factor ≤0.2 mm</td>
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<td>ASTM C 457</td>
<td>Standard Test Method for Microscopical Determination of Parameters of the Air.Void System in Hardened Concrete</td>
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<td>as specified</td>
<td>AASHTO M 295</td>
<td>ASTM C 618</td>
<td>Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete</td>
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<tr>
<td>as specified</td>
<td>AASHTO M 302</td>
<td>ASTM C 989</td>
<td>Standard Specification for Slag Cement for Use in Concrete and Mortars</td>
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<tr>
<td>as specified</td>
<td>AASHTO M 307</td>
<td>ASTM C 1240</td>
<td>Standard Specification for Silica Fume Used in Cementitious Mixtures</td>
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<td>ACCEPTANCE LIMIT</td>
<td>AASHTO DESIGNATION</td>
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<tr>
<td>as specified</td>
<td>AASHTO M157</td>
<td>ASTM C94 / C94M – 09</td>
<td>Standard Specification for ReadyMixed Concrete</td>
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<tr>
<td>as specified</td>
<td>AASHTO T 141</td>
<td>ASTM C 172</td>
<td>Standard Practice for Sampling Freshly Mixed Concrete</td>
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<tr>
<td>as specified procedures and calculation</td>
<td>AASHTO T 121</td>
<td>ASTM C 138/C 138M</td>
<td>Standard Test Method for Density, Unit Weight, Yield, and Air Content Gravimetric of Concrete</td>
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<tr>
<td>as specified procedures and calculation</td>
<td>AASHTO T 27</td>
<td>ASTM C 136</td>
<td>Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates</td>
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<tr>
<td>the drop of concrete to nearest 5mm</td>
<td>AASHTO T 119</td>
<td>ASTM C 143C 143M</td>
<td>Standard Test Method for Slump of Hydraulic.Cement Concrete</td>
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<td></td>
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<td>ASTM C 567</td>
<td>Equilibrium density will be approximately 80 to 160 Kg/m³ less than the fresh density</td>
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<tr>
<td>as specified</td>
<td>AASHTO T 126</td>
<td>ASTM C 192/C 192M</td>
<td>Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory</td>
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<tr>
<td>as specified procedures</td>
<td>AASHTO T 23</td>
<td>ASTM C 31/C 31M</td>
<td>Standard Practice for Making and Curing Concrete Test Specimens in the Field</td>
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<tr>
<td>as specified procedures and calculation</td>
<td>AASHTO T 22</td>
<td>ASTM C 39/C 39M</td>
<td>Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens</td>
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<td>as specified procedures</td>
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<td>ASTM C 172</td>
<td>Method of Sampling Freshly Mixed Concrete.</td>
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<tr>
<td>as specified procedures</td>
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<td>ASTM C 31</td>
<td>Practice for Making and Curing Concrete Test Specimens in the Field</td>
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<tr>
<td>as specified procedures</td>
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<td>ASTM C 42M</td>
<td>Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete</td>
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<tr>
<td>chloride limit (by mass of cement %) = 0.06 for prestressed concrete and 0.15 for reinforcement concrete in wet condition and 0.3 for reinforcement concrete in dry condition</td>
<td></td>
<td>ASTM C 1218</td>
<td>Standard Test Method for Water.Soluble Chloride in Mortar and Concrete</td>
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<tr>
<td>as specified procedures</td>
<td>AASHTO M 213</td>
<td>ASTM D 1751</td>
<td>Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction No extruding and Resilient Bituminous Types</td>
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<tr>
<td>as specified procedures</td>
<td>AASHTO M 153</td>
<td>ASTM D 1752</td>
<td>Standard Specification for Preformed Sponge Rubber Cork and Recycled PVC Expansion Joint Fillers for Concrete Paving and Structural Construction</td>
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<td>as specified procedures</td>
<td>AASHTO M 33</td>
<td>ASTM D 994</td>
<td>Standard Specification for Preformed Expansion Joint Filler for Concrete Bituminous Type</td>
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<td>as specified procedures</td>
<td></td>
<td>ASTM C 203</td>
<td>Standard Test Methods for Breaking Load and Flexural Properties of Block.Type Thermal Insulation</td>
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<tr>
<td>as specified procedures</td>
<td>AASHTO M 301</td>
<td></td>
<td>Joint sealants, Hot.Poured, for concrete and Asphalt Pavements</td>
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<td></td>
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<tr>
<td>ACCEPTANCE LIMIT</td>
<td>AASHTO DESIGNATION</td>
<td>ASTM DESIGNATION</td>
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<tr>
<td>Specific Gravity &lt;1.35 MPa</td>
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<td>ASTM D 792</td>
<td>Standard Test Methods for Density and Specific Gravity Relative Density of Plastics by Displacement</td>
<td></td>
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</tr>
<tr>
<td>Durometer Hardness = 75±5</td>
<td></td>
<td>ASTM D 2240</td>
<td>Standard Test Method for Rubber Property—Durometer Hardness</td>
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</tr>
<tr>
<td>Elongation = 350% and Tensile Strength = 12.41 MPa</td>
<td></td>
<td>ASTM D 412</td>
<td>Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension</td>
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<tr>
<td>Cold Brittness -37°C</td>
<td></td>
<td>ASTM D 746</td>
<td>Standard Test Method for Brittness Temperature of Plastics and Elastomers by Impact</td>
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<tr>
<td>Stiffness in Flexure = 2.4 MPa</td>
<td></td>
<td>ASTM D 747</td>
<td>Standard Test Method for Apparent Bending Modulus of Plastics by Means of a Cantilever Beam</td>
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<tr>
<td>as specified</td>
<td>AASHTO M 138M/M 138</td>
<td>ASTM B 152/B 152M</td>
<td>Standard Specification for Copper Sheet, Strip, Plate, and Rolled Bar</td>
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<tr>
<td>flexural strength of 240 kPa and a compressive yield strength of between 110 and 275 kPa, at five percent (5%) compression</td>
<td></td>
<td>ASTM C 203</td>
<td>Standard Test Methods for Breaking Load and Flexural Properties of Block-Type Thermal Insulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>no more than 55 kilograms of water per square meter should escape from the concrete slab in 72 hours</td>
<td>AASHTO M 148</td>
<td>ASTM C 309</td>
<td>Standard Specification for Liquid Membrane.Forming Compounds for Curing Concrete</td>
<td></td>
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<tr>
<td>plastic should be at least 4 miles thick, and reinforced with glass fibers</td>
<td>AASHTO M 171</td>
<td>ASTM C 171</td>
<td>Standard Specification for Sheet Materials for Curing Concrete</td>
<td></td>
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</table>
### Acceptance Limit

<table>
<thead>
<tr>
<th>Acceptance Limit</th>
<th>AASHTO Designation</th>
<th>ASTM Designation</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>One at least penetration resistance reading equals or exceeds [27.6 MPa]</td>
<td>AASHTO T 197</td>
<td>ASTM C 403/C 403M</td>
<td>Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance</td>
</tr>
<tr>
<td>As specified</td>
<td></td>
<td>ASTM D 2471</td>
<td>Standard Test Method for Gel Time and Peak Exothermic Temperature of Reacting Thermosetting Resins Withdrawn 2008</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO T 126</td>
<td>ASTM C 192</td>
<td>Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory</td>
</tr>
</tbody>
</table>

### The epoxy-bonding agent is acceptable if the load on the prisms at failure is greater than ninety percent (90%) of the load on the reference test beam at failure

<table>
<thead>
<tr>
<th>Acceptance Limit</th>
<th>AASHTO Designation</th>
<th>ASTM Designation</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>The epoxy-bonding agent is acceptable if the load on the prisms at failure is greater than ninety percent (90%) of the load on the reference test beam at failure</td>
<td>AASHTO T 97</td>
<td>ASTM C 78</td>
<td>Standard Test Method for Flexural Strength of Concrete Using Simple Beam with Third.Point Loading</td>
</tr>
</tbody>
</table>

### Compressive strength at twenty-five degree Celsius (25°C) shall be a minimum of 14 MPa after 24 h of curing at the minimum temperature of the designated application temperature range and 40 MPa at 48 h

<table>
<thead>
<tr>
<th>Acceptance Limit</th>
<th>AASHTO Designation</th>
<th>ASTM Designation</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>Compressive strength at twenty-five degree Celsius (25°C) shall be a minimum of 14 MPa after 24 h of curing at the minimum temperature of the designated application temperature range and 40 MPa at 48 h</td>
<td></td>
<td>ASTM D 695</td>
<td>Standard Test Method for Compressive Properties of Rigid Plastics</td>
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</table>

### A minimum deflection temperature of fifty degree Celsius (50°C) at fiber stress loading of 1.8 MPa is required on test specimens cured seven days at twenty-five degree Celsius (25°C)

<table>
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<th>Title</th>
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</thead>
<tbody>
<tr>
<td>A minimum deflection temperature of fifty degree Celsius (50°C) at fiber stress loading of 1.8 MPa is required on test specimens cured seven days at twenty-five degree Celsius (25°C)</td>
<td></td>
<td>ASTM D 648</td>
<td>Standard Test Method for Deflection Temperature of Plastics under Flexural Load in the Edgewise Position</td>
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</tbody>
</table>
The epoxy-bonding agent is acceptable for the designated application temperature range if the load on the slant cylinder specimen is greater than ninety percent (90%) of the load on the companion cylinder.

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>as specified</td>
<td>AASHTO T 22</td>
<td>ASTM C 39/C 39M</td>
<td>Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASTM C 845</td>
<td>Standard Specification for Expansive Hydraulic Cement</td>
</tr>
</tbody>
</table>

10.22. References
ACI 318 M.05 American concrete institute “Building Code Requirements For Structural Concrete And Commentary-2005”.

ACI 211.1 “Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete”.

ACI 211.2 “Standard Practice for Selecting Proportions for Structural Lightweight Concrete”.


ALABAMA. “Alabama Department of Transportation Standard Specifications for Highway Construction” Sec. 501.


MOT KSA;"General Specifications For Road And Bridge Construction"; November 1998. Sec. 5.03.
SECTION 11. REINFORCING STEEL

11.1. Description

This work shall consist of furnishing and placing reinforcing steel in accordance with these Specifications and in conformity with the contract documents.

11.1.1. General

All reinforcing bars shall be deformed except that plain bars may be used for spirals and ties.

Reinforcing steel shall conform to the requirements herein.

11.2. Materials

11.2.1. Coated Reinforcement

The reinforcing steel to be epoxy-coated shall conform to Article 11.2.2, "Uncoated Reinforcing".

When epoxy coating of reinforcing bars is required, the coating materials and process, the fabrication, handling, identification of the bars, and the repair of damaged coating that occurs during fabrication and handling, to the point of shipment to the job site, shall conform to the requirements of AASHTO M 284/M 284 (ASTM D 3963/D 3963M) or to ASTM A 934/A 934M, as specified in the contract documents.

Epoxy coated reinforcing bars shall be coated in a certified epoxy coating applicator plant in accordance with the Concrete Reinforcing Steel Institute Voluntary Certification Program for Fusion-Bonded Epoxy Coating Applicator Plants, or equivalent.

Epoxy-coated wire and welded wire fabric shall conform to the requirements of ASTM A 884/A 884M, Class A.

Each shipment of epoxy coated reinforcing steel shall be accompanied with a Certificate of Compliance signed by the applicator of the coating certifying that the epoxy coated reinforcing bars conform to the requirements of AASHTO M 317/M 317 (ASTM D 3963/D 3963M) and AASHTO M 284/M 284 (ASTM A 775/A 775M) or ASTM A 934/ A 934M, or that epoxy coated wire or welded wire fabric conforms to ASTM A 884/A 884M, Class A.

11.2.2. Uncoated Reinforcement

Uncoated reinforcing steel shall conform to one of the following specifications:

- Deformed and Plain Billet-Steel Bars for Concrete Reinforcement AASHTO M 31M/M 31 (ASTM A 615/A 615M). Grade 420 shall be used unless otherwise specified in the contract documents.

- Rail-Steel and Axle-Steel Plain Bars for Concrete Reinforcement AASHTO M 322M/M 322 (ASTM A 996/A 996M). Grade 420 steel shall be used unless otherwise specified in the contract documents.

- Low Alloy Steel Deformed and Plain Bars for Concrete Reinforcement ASTM A 706/A 706M.
- Deformed Steel Wire for Concrete Reinforcement AASHTO M 225/M 225 (ASTM A 496).
- Welded Plain Steel Wire Fabric for Concrete Reinforcement AASHTO M 55/M 55 (ASTM A 185).
- Plain Steel Wire for Concrete Reinforcement AASHTO M 32/M 32 (ASTM A 82).
- Steel Welded Wire Reinforcement, Deformed, for Concrete AASHTO M 221 M/M 221 (ASTM A 497).

11.2.3. Stainless Steel Reinforcing Bars
When specified in the contract document, deformed or plain stainless steel reinforcing bars shall conform to the requirements of ASTM A 955/A 955M.

11.2.4. Low Carbon, Chromium, Steel Reinforcing Bars
Where specified in the contract documents, deformed, low carbon, chromium, steel reinforcing bars shall conform to the requirements of ASTM A 1035/A 1035M.

11.2.5. Bar Lists and Bending Diagrams
When the contract documents do not include detailed bar lists and bending diagrams, the Contractor shall provide such lists and diagrams to the Engineer for review and approval. Fabrication of material shall not begin until such lists have been approved. The approval of bar lists and bending diagrams shall in no way relieve the Contractor of responsibility for the correctness of such lists and diagrams. Any expense occurred for the revision of material furnished in accordance with such lists and diagrams to make it comply with the design drawings shall be borne by the Contractor.

11.3. Fabrication

11.3.1. Bending
Bar reinforcement shall be cut and bent to the shapes shown in the contract documents. Tolerances shall be in accordance with ACI 315-92, "Detailing Manual". All bars shall be bent cold, unless otherwise permitted. Bars partially embedded in concrete shall not be field bent except as specified in the contract documents.

11.3.2. Hooks and Bend Dimensions
The dimensions of hooks and the diameters of bends measured on the inside of the bar shall be as shown in the contract documents. When the dimensions of hooks or the diameter of bends are not shown, they shall be in accordance with SBC 304, SBC 304C, Chapters 7 and 13.

11.3.3. Mill Test Reports
When steel reinforcing bars, other than bars conforming to ASTM A 706/A 706M, are to be spliced by welding or when otherwise requested, a certified copy of the mill test report showing physical and chemical analysis for each heat or lot of reinforcing bars delivered shall be provided to the Engineer.
11.4. Construction Methods

11.4.1. Handling, Storing and Surface Condition of Reinforcement

Steel reinforcement shall be stored above the surface of the ground on platforms, skids, or other supports and shall be protected from mechanical damage and surface deterioration caused by exposure to conditions producing rust. When placed in the work, reinforcement shall be free from dirt, loose rust or scale, mortar, paint, grease, oil, or other nonmetallic coatings that would reduce bond. Epoxy coatings of reinforcing steel in accord with standards in these Specifications shall be permitted. Reinforcement shall be free from defects such as cracks and laminations. Bonded rust, surface seams, surface irregularities, or mill scale shall not be cause for rejection, provided the minimum dimensions, cross-sectional area, and tensile properties of a hand wire-brushed specimen meet the physical requirements for the size and grade of steel specified.

Epoxy-coated reinforcing steel shall be handled and stored by methods that will not damage the epoxy coating. All systems for handling epoxy-coated reinforcement shall have adequately padded contact areas. All bundling bands shall be padded and all bundles shall be lifted with a strong back, multiple supports, or Platform Bridge so as to prevent bar-to-bar or wire-to-wire abrasion from sags in the bundles. Bars or bundles shall not be dropped or dragged. Epoxy-coated reinforcing steel shall be transported and stored on wooden or padded supports.

Epoxy-coated reinforcing steel shall be immediately protected from sunlight, salt spray, and weather exposure. Provisions shall be made for air circulation around the protected reinforcement to minimize condensation under the protective covering.

11.4.2. Placing and Fastening

11.4.2.1. General

Steel reinforcement shall be accurately placed as shown in the contract documents and firmly held in position during the placing and consolidation of concrete. Bars shall be tied at all intersections around the perimeter of each mat and at not less than 600 mm centers or at every intersection, whichever is greater, elsewhere. Bundled bars shall be tied together at not more than 1.8 m centers. For fastening epoxy-coated reinforcement, tie wire and metal clips shall be plastic coated or epoxy-coated. If uncoated welded wire fabric is shipped in rolls, it shall be straightened into flat sheets before being placed. Welding of crossing bars (tack welding) shall not be permitted for assembly of reinforcement unless authorized in writing by the Engineer.

11.4.2.2. Support Systems

Reinforcing steel shall be supported in its proper position by use of precast concrete blocks, wire bar supports, supplementary bars, or other approved devices. Such reinforcing supports or devices shall be of such height and placed at sufficiently frequent intervals so as to maintain the distance between the reinforcing steel and the formed surface or the top surface of deck slabs within 6 mm of that indicated in the contract documents.

Platforms for the support of workers and equipment during concrete placement shall be supported directly on the forms and not on the reinforcing steel.
11.4.2.3. Precast Concrete Blocks

Precast concrete blocks shall have a compressive strength not less than that of the concrete in which they are to be embedded. The face of blocks in contact with forms for exposed surfaces shall not exceed 50×50 mm in size and shall have a color and texture that will match the concrete surface. When used on vertical or sloping surfaces, such blocks shall have an embedded wire for securing the block to the reinforcing steel. When used in slabs, either such a tie wire or, when the weight (mass) of the reinforcing is sufficient to firmly hold the blocks in place, a groove in the top of the block may be used. For epoxy-coated bars, such tie wires shall be plastic-coated or epoxy-coated.

11.4.2.4. Wire Bar Supports

Wire bar supports, such as ferrous metal chairs and bolsters, shall conform to industry practice as described in the Manual of Standard Practice of the Concrete Reinforcing Steel Institute. Such chairs or bolsters which bear against the forms for exposed surfaces shall be either Class 1-Maximum Protection (Plastic Protected) or Class 2, Type B-Moderate Protection (Stainless Steel Tipped) for which the stainless steel conforms to ASTM A 493, Type 430. For epoxy-coated reinforcement, all wire bar supports and bar clips shall be plastic-coated or epoxy-coated.

11.4.2.5. Adjustments

Non prestressed reinforcement used in post-tensioned concrete shall be adjusted or relocated during the installation of prestressing ducts or tendons, as required to provide planned clearances to the prestressing tendons, anchorages, and stressing equipment, as approved by the Engineer.

11.4.2.6. Repair of Damaged Epoxy Coating

In addition to the requirements of Article [11.2.1], "Epoxy-Coated Reinforcing", all damaged coating on epoxy-coated reinforcing steel that occurs during shipment, handling, and placing of the reinforcing steel shall be repaired. The maximum amount of repaired damaged areas shall not exceed two percent of the surface area in each 300 mm bar length. Should the amount of damaged coating incurred during shipment, handling and placing exceed two percent of the surface area in each 300 mm bar length, that bar shall be removed and replaced with an acceptable epoxy coated bar. The sum of the areas covered with patching material applied during repairs at all stages of the work shall not exceed five percent of the total surface area of any bar. The patching material shall be pre-qualified as required for the coating material and shall be either identified on the container as meeting the requirements of Annex A1 of AASHTO M 317M/M 317 (ASTM D 3963/D 3963M) and AASHTO M 284M/M 284 (ASTM A 775/A 775M) or Annex A1 of ASTM A 934/A 934M, or shall be accompanied by a Certificate of Compliance certifying that the material meets the requirements of said Annex A1. Patching of damaged areas shall be performed in accordance with the patching material Manufacturer's recommendations. Patches shall be allowed to cure before placing concrete over the coated bars.

11.4.3. Splicing of Bars

11.4.3.1. General

All reinforcement bars shall be furnished in the full lengths as specified in the contract documents, unless otherwise permitted. Except for splices specified in the contract documents and splices for 16 mm diameter or smaller bars, splicing of bars
shall not be permitted without written approval by the Engineer. Splices shall be staggered as far as possible.

11.4.3.2. Lap Splices
Lap splices shall be of the lengths specified in the contract documents. If not specified in the contract documents, the length of lap splices shall be in accordance with Article 5.16.5.3.1 or Article 5.16.5.5.1 of the (MA-100-D-V1/2), or as approved by the Engineer.

In lap splices, the bars shall be placed and tied in such a manner as to maintain the minimum distance to the surface of the concrete specified in the contract documents. Lap splices shall not be used for 40 mm and 50 mm diameter bars, except as provided in either Article 5.16.5.2.1 or Article 5.16.5.5.1 of the (MA-100-D-V1/2).

11.4.3.3. Welded Splices
Welded splices of reinforcing bars shall be used only if detailed in the contract documents or if authorization is made by the Engineer in writing. Welding shall conform to the ANSI/ AWS D 1.4 Structural Welding Code Reinforcing Steel and the contract documents.

Welded splices shall not be used on epoxy-coated reinforcing bars. To avoid heating of the coating, no welding shall be performed in close proximity to epoxy coated bars.

Welded splices for deformed, low carbon, chromium, steel reinforcing bars conforming to ASTM A 1035/A 1035M shall not be used.

11.4.3.4. Mechanical Splices
Mechanical splices shall be used only if pre-approved or detailed in the contract documents or authorized in writing by the Engineer. Such mechanical splices shall develop in tension or compression, as required, at least one hundred and twenty-five percent (125%) of the specified yield strength of the bar being spliced.

When requested by the Engineer, up to two field splices out of each 100, or portion thereof, placed in the work and chosen at random by the Engineer, shall be removed by the Contractor and tested by the Engineer for compliance to the required one hundred and twenty-five percent (125%) of the specified yield strength of the bars being spliced.

11.4.3.5. Splicing of Welded Wire Fabric
Sheets of welded wire fabric shall be spliced by overlapping each other sufficiently to maintain a uniform strength and shall be securely fastened at the ends and edges. The edge lap shall not be less than one mesh in width plus 50 mm.

11.4.4. Substitutions
Substitution of different size reinforcing bars shall be permitted only when authorized by the Engineer. The substituted bars shall have an area equivalent to the design area or larger, and shall be in accordance with Article 5.7.3.4 of the (MA-100-D-V1/2).

11.5. Works Acceptance
All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and this section
requirements. For work acceptance, Contractor shall apply quality control for manufacturing and installation of reinforcing steel work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.

The Ministry shall apply quality assurance and verify the Contractor quality control procedures either through direct supervision or by carrying out neutrally quality assurance procedures using test on representative samples and in adequate numbers to judge about the quality level and accept or reject the executed works according to the principles detailed mentioned bellow in next paragraphs.

11.5.1. Quality Control

All reinforcing works in should be controlled according to the requirements of steel materials production of the article 11.2.1 for coated reinforcement and article 11.2.2 for uncoated reinforcement, all deforming steel plans should be reviewed and checked to assure that it is correct and conforming the requirements of article 11.2.3.

Factory test reports should be reviewed and insure that the quality of production and fabrication is confirming to the specification of this section and the Table 11.5.

For work acceptance, all Placing, Fastening and splicing of the reinforcement steel should be conforming the section of the article 11.4.2 and article 11.4.3.

11.5.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of reinforcing steel work, fabrication, furnishing process handling and placing are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that insure the quality of reinforcing steel work. That can be done by asking the manufacture test results and construction plans.

11.6. Measurement and Payment

11.6.1. Measurement

Measurement of "Reinforcing Steel" shall be based on the theoretical number of tons complete in place as shown on the plans or placed as ordered in writing by the Engineer.

The mass of reinforcement used in items such as railings and precast members, where payment for the reinforcement is included in the contract price for the item, shall not be included. Threaded bars or dowels placed after the installation of precast members in the work and used to attach such members to cast-in-place concrete shall be included.

No allowance shall be made for clips, wire, separators, wire chairs, and other material used in fastening the reinforcement in place. If bars are substituted upon the Contractor's request and as a result more reinforcing steel is used than specified in the contract documents, only the amount specified in the contract documents shall be included.

The additional reinforcing steel required for splices that are not shown in the contract documents, but are authorized as provided herein, shall not be included.

No allowance shall be made for the mass of epoxy coating in computing the mass of epoxy coated reinforcing steel.
Calculated weights shall be based from the tables given below:

**Table 11.1: Standard Reinforcing Bars (SBC)**

<table>
<thead>
<tr>
<th>Bar designation</th>
<th>Nominal diameter, mm</th>
<th>Nominal area, mm$^2$</th>
<th>Nominal mass, kg/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dia. 6</td>
<td>6</td>
<td>28</td>
<td>0.222</td>
</tr>
<tr>
<td>Dia. 8</td>
<td>8</td>
<td>50</td>
<td>0.395</td>
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<tr>
<td>Dia. 10</td>
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<td>79</td>
<td>0.617</td>
</tr>
<tr>
<td>Dia. 12</td>
<td>12</td>
<td>113</td>
<td>0.888</td>
</tr>
<tr>
<td>Dia. 14</td>
<td>14</td>
<td>154</td>
<td>1.21</td>
</tr>
<tr>
<td>Dia. 16</td>
<td>16</td>
<td>201</td>
<td>1.58</td>
</tr>
<tr>
<td>Dia. 18</td>
<td>18</td>
<td>254</td>
<td>2.00</td>
</tr>
<tr>
<td>Dia. 20</td>
<td>20</td>
<td>314</td>
<td>2.47</td>
</tr>
<tr>
<td>Dia. 22</td>
<td>22</td>
<td>380</td>
<td>2.98</td>
</tr>
<tr>
<td>Dia. 25</td>
<td>25</td>
<td>491</td>
<td>3.85</td>
</tr>
<tr>
<td>Dia. 28</td>
<td>28</td>
<td>616</td>
<td>4.83</td>
</tr>
<tr>
<td>Dia. 32</td>
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<td>804</td>
<td>6.31</td>
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<tr>
<td>Dia. 36</td>
<td>36</td>
<td>1018</td>
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<tr>
<td>Dia. 40</td>
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<td>9.87</td>
</tr>
<tr>
<td>Dia. 45</td>
<td>45</td>
<td>1590</td>
<td>12.5</td>
</tr>
<tr>
<td>Dia. 50</td>
<td>50</td>
<td>1963</td>
<td>15.4</td>
</tr>
</tbody>
</table>

**Table 11.2: Standard Wire Reinforcement (SBC)**

<table>
<thead>
<tr>
<th>Wire Designation</th>
<th>Nominal Diameter, mm</th>
<th>Nominal area, mm$^2$</th>
<th>Nominal mass, kg/m</th>
<th>Area (As, mm$^2$) per meter</th>
<th>Center-to-center spacing, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>WD 4.0</td>
<td>4</td>
<td>12.6</td>
<td>0.099</td>
<td>252</td>
<td>168</td>
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<tr>
<td>WD 4.5</td>
<td>4.5</td>
<td>15.9</td>
<td>0.125</td>
<td>318</td>
<td>212</td>
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<tr>
<td>WD 5.0</td>
<td>5</td>
<td>19.6</td>
<td>0.154</td>
<td>392</td>
<td>261</td>
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<tr>
<td>WD 5.5</td>
<td>5.5</td>
<td>23.8</td>
<td>0.187</td>
<td>476</td>
<td>317</td>
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<tr>
<td>WD 6.0</td>
<td>6</td>
<td>28.3</td>
<td>0.222</td>
<td>566</td>
<td>377</td>
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<tr>
<td>WD 6.5</td>
<td>6.5</td>
<td>33.2</td>
<td>0.26</td>
<td>664</td>
<td>443</td>
</tr>
<tr>
<td>WD 7.0</td>
<td>7</td>
<td>38.5</td>
<td>0.302</td>
<td>770</td>
<td>513</td>
</tr>
<tr>
<td>WD 7.5</td>
<td>7.5</td>
<td>44.2</td>
<td>0.347</td>
<td>884</td>
<td>589</td>
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<tr>
<td>WD 8.0</td>
<td>8</td>
<td>50.3</td>
<td>0.396</td>
<td>1006</td>
<td>671</td>
</tr>
</tbody>
</table>
Section 11: Reinforcing Steel

Reinforcing Steel Measurement and Payment

<table>
<thead>
<tr>
<th>Wire Designation</th>
<th>Nominal Diameter, mm</th>
<th>Nominal area, mm²</th>
<th>Nominal mass, kg/m</th>
<th>Area (As, mm²) per meter Center-to-center spacing, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>WD 8.5</td>
<td>8.5</td>
<td>56.7</td>
<td>0.445</td>
<td>1134</td>
</tr>
<tr>
<td>WD 9.0</td>
<td>9</td>
<td>63.6</td>
<td>0.499</td>
<td>1272</td>
</tr>
<tr>
<td>WD 9.5</td>
<td>9.5</td>
<td>70.9</td>
<td>0.556</td>
<td>1418</td>
</tr>
<tr>
<td>WD 10.0</td>
<td>10</td>
<td>78.5</td>
<td>0.617</td>
<td>1570</td>
</tr>
<tr>
<td>WD 10.5</td>
<td>10.5</td>
<td>86.6</td>
<td>0.68</td>
<td>1732</td>
</tr>
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<td>WD 11.0</td>
<td>11</td>
<td>95</td>
<td>0.746</td>
<td>1900</td>
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<td>11.5</td>
<td>103.9</td>
<td>0.815</td>
<td>2078</td>
</tr>
<tr>
<td>WD 12.0</td>
<td>12</td>
<td>113.1</td>
<td>0.888</td>
<td>2262</td>
</tr>
</tbody>
</table>

No allowance will be made for the weight of weld metal used in the fabrication of bar trusses. No measurement will be made for welded (mesh) steel reinforcement or cold drawn steel wire as they are considered subsidiary to the construction of the item in which they are placed.

11.6.2. Payment

The amount of completed and accepted material, measured as provided above, will be paid for at the contract unit price per ton of Reinforcing Steel and Epoxy Coated Reinforcing Steel, as specified in the Bill of Quantities, which price and payment shall be full compensation for furnishing, fabricating, transporting, delivering, erecting, and placing all materials, including all labor, equipment, tools, and all other items necessary for the proper completion of the Work as specified in Contract Documents.

Payment will be made under one or more of the items in Table 11.3, the quality control requirements of reinforcing steel are shown in Table 11.4.

Table 11.3: Reinforcing Steel Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.2.1</td>
<td>Coated Reinforcement</td>
<td>Ton</td>
</tr>
<tr>
<td>11.2.2</td>
<td>Uncoated Reinforcement</td>
<td>Ton</td>
</tr>
<tr>
<td>11.2.3</td>
<td>Stainless Steel Reinforcing Bars</td>
<td>Ton</td>
</tr>
<tr>
<td>11.2.4</td>
<td>Low Carbon, Chromium, Steel Reinforcing Bars</td>
<td>Ton</td>
</tr>
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</table>
Table 11.4: Quality Control Requirements For Reinforcing Steel

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bars tied</td>
<td>Not less than 600 mm or at every intersection</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>---------------------</td>
<td>Article 11.4.2.1</td>
</tr>
<tr>
<td>Bundled bars</td>
<td>Tied together at not more than 1.8 m centers</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>---------------------</td>
<td>Article 11.4.2.1</td>
</tr>
<tr>
<td>splices specified in the contract documents</td>
<td>For 16 mm diameter or smaller bars</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>---------------------</td>
<td>Article 11.4.2.1</td>
</tr>
<tr>
<td>Lap Splices</td>
<td>Not be used for 40 mm and 50 mm diameter bars</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>---------------------</td>
<td>Article 11.4.3.2</td>
</tr>
<tr>
<td>Welded Splices</td>
<td>Conform to the ANSI/ AWS D 1.4 Structural Welding Code Reinforcing Steel</td>
<td>Assurance</td>
<td>In situ</td>
<td>---------------------</td>
<td>Article 11.4.3.3</td>
</tr>
</tbody>
</table>

Table 11.5: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>as specified</td>
<td>AASHTO M 284M/M 284</td>
<td>(ASTM A 775/A 775M)</td>
<td>Standard Specification for Epoxy-Coated Steel Reinforcing Bars.</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 31M/M 31</td>
<td>(ASTM A 615/A 615M)</td>
<td>Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 322M/M 322</td>
<td>(ASTM A 996/A 996M)</td>
<td>Standard Specification for Rail-Steel and Axle-Steel Deformed Bars for Concrete Reinforcement.</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM A 706/A 706M</td>
<td></td>
<td>Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement.</td>
</tr>
</tbody>
</table>
11.7. References
ACI 315-92, “American Concrete Institute-1990 – "Detailing Manual".


OKLAHOMA. “Oklahoma Department of Transportation Standard Specifications for Highway Construction” Sec. 506


SBC304, Saudi building code “Structural – Concrete Structures (details of reinforcement)” -2007

SBC 304C Saudi Building Code “concrete structural requirements Commentary, Chapter 7and 13-2007”.

MOMRA: Kingdom of Saudi Arabia Ministry of Municipal & Rural Affairs Deputy Ministry for Technical Affairs –"Bridges Design Specifications" (MA-100-D-V1/2 & V2/2)- 2013.
SECTION 12. PRESTRESSING

12.1. General

12.1.1. Description

This work shall consist of pre-stressing precast or cast-in-place concrete by furnishing, placing, and tensioning of pre-stressing steel in accordance with details shown on the plans, and as specified in these specifications and the special provisions. It includes pre-stressing by either the pretensioning or post-tensioning methods or by a combination of these methods.

This work shall include the furnishing and installation of any appurtenant items necessary for the particular prestressing system under consideration by the Contractor, including but not limited to ducts, anchorage assemblies, grout used for pressure grouting ducts, and gauges and testing equipment to assess various prestressing parameters.

When members are to be constructed with part of the reinforcement pre-tensioned and part post-tensioned, the applicable requirement of this Specification shall apply to each method.

12.1.2. Definitions

The term "Pre-Tensioned-Prestressed Concrete" refers to concrete in which the pre-stressing strands or wire are tensioned prior to placing the concrete and released after the concrete has gained sufficient strength to retain the pre-stressing force by bond.

The term "Post-Tensioned Prestressed Concrete" refers to concrete in which the stressing steel is installed in voids or ducts cast within the concrete member, and is stressed and anchored after the concrete has developed a specified strength. As a final operation, the voids or ducts are filled with grout under pressure.

For cast-in-place prestressed concrete, the term "Member" as used in this section shall be considered to mean the concrete stated for prestress.

12.1.3. Detail of Design

When the design for the pre-stressing work is not fully detailed on the plans, the Contractor shall furnish the details or type of pre-stressing system for use and select materials and details conforming to these Specifications as needed to satisfy the specified pre-stressing requirements. The system selected shall provide the magnitude and distribution of pre-stressing force and ultimate strength required by the plans without exceeding allowable temporary stresses. Unless otherwise shown on the plans, all design procedures, coefficients and allowable stresses, friction and pre-stress losses as well as tendon spacing and clearances shall be in accordance with (MA-100-D-V1/2 & V2/2) as applicable.

The pre-stressing may be performed by either pretensioning or post-tensioning methods. If the plans show only pretensioning details, the use of a post-tensioning system will be allowed only if complete details of any necessary modifications are approved by the Engineer.
When the effective or working force or stress is shown on the plans, it shall be considered to be the force or stress remaining in the pre-stressing steel after all losses, including creep and shrinkage of concrete, elastic shortening of concrete, relaxation of steel, friction and take up or seating of anchorages, and all other losses particular to the method or system of pre-stressing have taken place or have been accounted for. When the jacking force is shown on the plans, it shall be considered to be the force applied to the tendon prior to anchorage and the occurrence of any losses, including the anchor set loss.

12.2. Supplementary Drawings

12.2.1. Working Drawings and Shop Drawings

Where the contract documents do not include complete details of the pre-stressing system and its method of installation, or when complete details are provided in the plans and the Contractor wishes to propose any change, the Contractor shall prepare and submit to the Engineer working drawings of the pre-stressing system proposed for use. Fabrication or installation of pre-stressing material shall not begin until the Engineer has approved the drawings.

The working drawings of the pre-stressing system shall show complete details and substantiating calculations of the method, materials and equipment the Contractor proposes to use in the pre-stressing operations, including any additions or rearrangement of reinforcing steel and any revision in concrete dimensions from that in the contract documents. Such details shall outline the method and sequence of stressing and shall include complete specifications and details of the pre-stressing steel and anchoring devices, working stresses, anchoring stresses, tendon elongations, type of ducts, and all other data pertaining to the pre-stressing operation, including the proposed arrangement of the pre-stressing steel in the members.

Working drawings shall be submitted sufficiently in advance of the start of the affected work to allow time for review by the Engineer and correction by the Contractor of the drawings without delaying the work.

Where required on the contract drawings or in the contract documents, the contractor shall prepare integrated drawings for all items embedded in the concrete. If this provision includes a requirement for additional engineering or design detailing, these requirements shall be clearly stated, as noted in Article 12.1.3.

Shop drawings for post-tensioning and other embedments and attachments, such as expansion joints, bearings, and anchor bolts submitted by suppliers shall be reviewed and approved by the Engineer for conformance with the design concept and compliance with the design.

Drawings and specifications: Where contract-document information on post-tensioning system is modified by the contractor, or where the contract drawings do not provide detailed dimensional information on the post-tensioning system, it is the contractor’s responsibility to coordinate the placement of the post-tensioning system with other embedments, and to correct any interferences created by the contractor-supplied PT system or other substitutions. The Post-tensioning layout shall govern the layout of the secondary non-prestressed reinforcement. Where necessary, location of non-prestressed reinforcement should be adjusted to clear tendons, subject to approval of the Engineer.
12.2.2. Integrated Drawings

Where required by the contract documents, in addition to all required working drawings, the Contractor shall prepare composite placement drawings to scale and in sufficient detail to show the relative positions of all items that are to be embedded in the concrete, and their embedment depth, for the portions of the structure that are to be prestressed. Such embedded items shall include the pre-stressing ducts, vents, anchorage reinforcement and hardware, reinforcing steel, anchor bolts, earthquake restrainers, deck joint seal assemblies, drainage systems, utility conduits and other such items. Such drawings shall be adequate to ensure that there will be no conflict between the planned positions of any embedded items and that concrete cover will be adequate. Where the contract calls for the contractor to develop drawings for post-tensioning systems, or where the contractor makes modifications to the post-tensioning system(s) shown on the plans, the contractor shall prepare working drawings for embedded items or propose changes in the dimensions of the work as necessary to eliminated conflicts and provide proper cover wherever conflicts arise with or due to the post-tensioning system. Resolution of the conflicts should follow the provision of Article [12.1.3]. Any such revisions shall be approved by the Engineer before work on any affected item is started. All costs involved with the preparation of such drawings and with making the necessary modifications to the work resulting there from shall be borne by the contractor. This will require integrated drawings to be detailed to a scale and sufficient quality to show double-line reinforcement and post-tensioning tendon details in either two-dimensional or in complete three-dimensional drawings.

12.3. Submittals

The Contractor shall submit to the Engineer for review and approval set of working drawings of the pre-stressing system proposed for use. For initial review, six (6) sets of such drawings shall be submitted. The Engineer shall return one (1) approved set or one (1) set with corrections and modifications. After modification, six (6) sets of the drawings (and their associated calculations if any) showing any required corrections shall be submitted for final approval. Working drawings shall be submitted sufficiently in advance of the start of the affected work to allow time for review by the Engineer and correction by the Contractor of the drawings without delaying the approved programmed commencement of the Work. Such time shall be proportional to the complexity of the work but, in no case, shall such time be less than two months.

The working drawings of the pre-stressing system shall show complete details and substantiating calculations of the method and materials that the Contractor proposes to use in the pre-stressing operations, including any additions or rearrangement of reinforcing steel and any revision in concrete dimensions from that shown on the plans. Such details shall outline the method and sequence of stressing and shall include complete specifications and details of the pre-stressing steel and anchoring devices, working stresses, anchoring stresses, stress-strain curves of the pre-stressing steel, anticipated gauge pressures, cable profiles, elongation of pre-stressing cables, type of ducts and all other data pertaining to the pre-stressing operation, including the proposed arrangement of the pre-stressing steel in the members.

The designs shall be prepared by an expert who has been approved in advance by the Engineer.

Approval of working drawings and other submittals does not absolve the Contractor of the responsibility for any of his Contractual obligations. No additional payment will be made to the Contractor for any changes required as a result of reviews or approvals.
The Contractor shall submit for approval experience records and qualification
details of all the Contractor's key structural design, fabrication, installation, and quality
control personnel who will be working on the pre-stressing and concrete operation.
Once approved, the Contractor shall not change or substitute any of the personnel
without the prior approval of the Engineer.

All criteria covered by this Section on submittals and approval shall also apply to
any subcontractor conducting any of the respective prestressed concrete work.

12.4. Materials

12.4.1. Pre-stressing Reinforcement

12.4.1.1. Pre-stressing Steel and Anchorage

Pre-stressing reinforcement shall be high-strength seven-wire strand, high-strength
steel wire, or high strength alloy bars of the grade and type called for on the plans or in
the special provisions and shall conform to the requirements of the following
Specifications.

1. Strand

Uncoated seven-wire strand shall conform to the requirements of AASHTO M
203M/M 203 (ASTM A 416/A 416M). Supplement S1 (Low-Relaxation) shall apply
when specified.

2. Wire

Uncoated stress-relieved steel wire shall conform to the requirements of AASHTO
M 204 (ASTM A 421/A 421 M).

3. Bars

Uncoated high-strength bars shall conform to the requirements of AASHTO M
275M/M 275 (ASTM A 722/A 722M). Bars with greater minimum ultimate strength,
but otherwise produced and tested in accordance with AASHTO M 275M/M 275
(ASTM A 722/A 722M), may be used provided they have no properties that make them
less satisfactory than the specified material.

12.4.1.2. Post-Tensioning Anchorage and Couplers

All anchorages and couplers shall develop at least ninty-five percent (95%) of the
actual ultimate strength of the pre-stressing steel, when tested in an unbonded state,
without exceeding anticipated set. The coupling of tendons shall not reduce the
elongation at rupture below the requirements of the tendon itself. Couplers and/or
coupler components shall be enclosed in housings long enough to permit the necessary
movements. Couplers for tendons shall be used only at locations specifically indicated
and/or approved by the Engineer. Couplers shall not be used at points of sharp tendon
curvature.

1. Bonded System

Bond transfer lengths between anchorages and the zone where full pre-stressing
force is required under service and ultimate loads shall normally be sufficient to
develop the minimum specified ultimate strength of the pre-stressing steel. When
anchorages or couplers are located at critical sections under ultimate load, the ultimate
strength required of the bonded tendons shall not exceed the ultimate capacity of the tendon assembly, including the anchorage or coupler, tested in an unbonded state. Housings shall be designed so that complete grouting of all of the coupler components will be accomplished during grouting of tendons.

2. Unbonded System

For unbonded tendons, a dynamic test shall be performed on a representative anchorage and coupler specimen and the tendon shall withstand, without failure, 500,000 cycles from sixty percent (60%) to sixty-six percent (66%) of its minimum specified ultimate strength, and also 50 cycles from forty percent (40%) to eighty percent (80%) of its minimum specified ultimate strength. The period of each cycle involves the change from the lower stress level to the upper stress level and back to the lower. The specimen used for the second dynamic test need not be the same used for the first dynamic test. Systems utilizing multiple strands, wires, or bars may be tested utilizing a test tendon of smaller capacity than the full-sized tendon. The test tendon shall duplicate the behavior of the full-sized tendon and generally shall not have less than ten percent (10%) of the capacity of the full-sized tendon. Dynamic tests are not required on bonded tendons, unless the anchorage is located or used in such manner that repeated load applications can be expected on the anchorage.

Anchorages for unbonded tendons shall not cause a reduction in the total elongation under ultimate load of the tendon to less than two percent (2%) measured in a minimum gauge length of 3 m.

All the coupling components shall be completely protected with a coating material prior to final encasement in concrete.

3. Special Anchorage Device Acceptance Test

a. Test Block Requirement

The test block shall be a rectangular prism. It shall contain those anchorage components which will also be embedded in the structure's concrete. Their arrangement has to comply with the practical application and the suppliers specifications. The test block shall contain an empty duct of size appropriate for the maximum tendon size which can be accommodated by the anchorage device.

![Figure 12.2: Special Anchorage Device Acceptance Test Specimen.](image)
b. Test Block Dimensions

The dimensions of the test block perpendicular to the tendon in each direction shall be the smaller of the minimum edge distance or the minimum spacing specified by the anchorage device supplier, with the stipulation that the cover over any confining reinforcing steel or supplementary skin reinforcement be appropriate for the particular application and environment. The length of the block along the axis of the tendon shall be at least two times the larger of the cross-section dimensions.

c. Local Zone Reinforcement

The confining reinforcing steel in the local zone shall be the same as that specified by the anchorage device supplier for the particular system.

d. Skin Reinforcement

In addition to the anchorage device and its specified confining reinforcement steel, supplementary skin reinforcement may be provided throughout the specimen. This supplementary skin reinforcement shall be specified by the anchorage device supplier but shall not exceed a volumetric ratio of 0.01.

e. Concrete Strength

The concrete strength at the time of stressing shall be greater than the concrete strength of the test specimen at time of testing.

f. Test Procedure

Any of the following three test procedures is acceptable:

- Cyclic loading described in the Article 12.4.1.2.3.g
- Sustained loading described in the Article 12.4.1.2.3.h
- Monotonic loading described in the Article 12.4.1.2.3.i

The loads specified for the tests are given in fractions of the ultimate load $F_{pu}$ of the largest tendon that the anchorage device is designed to accommodate. The specimen shall be loaded in accordance with normal usage of the device in post-tensioning applications except that load can be applied directly to the wedge plate or equivalent area.

g. Cyclic Loading Test

In a cyclic loading test, the load shall be increased to 0.8 $F_{pu}$. The load shall then be cycled between 0.1 $F_{pu}$ and 0.8 $F_{pu}$ until crack widths stabilize, but for not less than 10 cycles. Crack widths are considered stabilized if they do not change by more than 0.025 mm over the last three readings. Upon completion of the cyclic loading the specimen shall be preferably loaded to failure or, if limited by the capacity of the loading equipment, to at least 1.1 $F_{pu}$.

Crack widths and crack patterns shall be recorded at the initial load of 0.8 $F_{pu}$ at least at the last three consecutive peak loadings before termination of the cyclic loading, and at 0.9 $F_{pu}$. The maximum load shall also be reported.

h. Sustained Loading Test

In a sustained loading test, the load shall be increased to 0.8 $F_{pu}$ and held constant until crack widths stabilize but for not less than 48 hours. Crack widths are considered stabilized if they do not change by more than 0.025 mm over the last three readings.
After sustained loading is completed, the specimen shall be preferably loaded to failure or, if limited by the capacity of the loading equipment, to at least 1.1 $F_{pu}$.

Crack widths and crack patterns shall be recorded at the initial load of 0.8 $F_{pu}$ at least three times at intervals of not less than 4 hours during the last 12 hours before termination of the sustained loading, and during loading to failure at 0.9 $F_{pu}$. The maximum load shall also be reported.

**i. Monotonic Loading Test**

In a monotonic loading test, the load shall be increased to 0.9 $F_{pu}$ and held constant for 1 hour. The specimen shall then be preferably loaded to failure or, if limited by the capacity of the loading equipment, to at least 1.2 $F_{pu}$.

Crack widths and crack patterns shall be recorded at 0.9 $F_{pu}$ after the 1-hour period, and at 1.0 $F_{pu}$. The maximum load shall also be reported.

**j. Anchorage Zone Requirement**

The strength of the anchorage zone must exceed:

- Specimens tested under cyclic or sustained loading: $1.1 F_{pu}$
- Specimens tested under monotonic loading: $1.2 F_{pu}$

The maximum crack width criteria specified below must be met for moderately aggressive environments.

- No cracks greater than 0.25 mm at 0.8 $F_{pu}$ after completion of the cyclic or sustained loading, or at 0.9 $F_{pu}$ after the 1-h period for monotonic loading.
- No cracks greater than 0.4 mm at 0.9 $F_{pu}$ after completion of the cyclic or sustained loading, or at 1.0 $F_{pu}$ for monotonic loading.

For high aggressive environments the crack width criteria shall be reduced by at least fifty percent (50%).

**k. Test Series Requirement**

A test series shall consist of three test specimens. Each one of the tested specimens must meet the acceptance criteria. If one of the three specimens fails to pass the test, a supplementary test of three additional specimens is allowed. The three additional test specimen results must meet all acceptance criteria of Article 12.4.1.2.3.f.

For a series of similar special anchorage devices, tests are only required for representative samples unless tests for each capacity of the anchorages in the series are required by the Engineer.

**l. Records of the Anchorage Device**

Records of the anchorage device acceptance test shall include:

1. Dimensions of the test specimen.
2. Drawings and dimensions of the anchorage device, including all confining reinforcing steel.
3. Amount and arrangement of supplementary skin reinforcement.
4. Type and yield strength of reinforcing steel.
5. Type and compressive strength at time of testing of concrete.
6. Type of testing procedure and all measurements required in Article 12.4.1.2.3.f for each specimen.
12.4.2. Grout

Post-tensioning grout shall meet the grout physical properties stated in Article 12.4.2.3 "Grout Physical Properties." Grouts may be either a unique design for the project or supplied in a prebagged form by a grout Manufacturer. For uniquely designed grouts, the cement and admixtures utilized in the laboratory trial batches of the proposed grout shall not be changed during the construction without retesting. Freshness of the cement shall be in accordance with AASHTO M 85 (ASTM C 150), except as specified herein. Daily field testing of the grout for the following properties shall be required:
- Fluidity
- Bleed at 3 h, and
- Permeability

A preapproved, prebagged grout supplied by a grout manufacturer may be used as an alternative to the required field testing. These grouts shall be prebagged in plastic lined or coated containers, stamped with date of manufacture, lot number, and mixing instructions. Any change of materials or material sources shall require retesting and certification of the conformance of the grout with the physical properties requirements. A copy of the Quality-Control Data Sheet for each lot number and shipment sent to the job site shall be provided to the Contractor by the grout supplier and shall be furnished to the Engineer. Materials with total time from manufacture to usage is excess of six months shall be removed from the job site and replaced.

12.4.2.1. Approval

Manufacturers of post-tensioning grout shall submit for approval certified test reports from an audited and independent Cement Concrete Research Laboratory (CCRL) which shows the material meets all the requirements specified herein.

12.4.2.2. Mixing

The material shall be mixed in accordance with the Manufacturer's recommendations.

The water used in the grout shall be potable, clean, and free of injurious quantities of substances known to be harmful to Portland Cement or pre-stressing steel.

12.4.2.3. Grout Physical Properties

Grouts shall achieve a nonbleeding characteristic. Grout shall contain no aluminum powder or gas generating system that produces hydrogen, carbon dioxide, or oxygen. Cementitious grout shall meet or exceed the specified physical properties stated herein as determined by the following standard and modified ASTM test methods.

Grout Classes shall be taken as specified in Article 12.4.2 and Grout Properties shall be as specified in Table 12.1 and Table 12.2.
### Table 12.1: Grout Classes

<table>
<thead>
<tr>
<th>Class</th>
<th>Exposure</th>
<th>Cement kg</th>
<th>Fly Ash (type F) % a</th>
<th>Slag % a</th>
<th>Silica Fume (dry) % a</th>
<th>Water/Cementitious Material Ratio [W/(c+m)]</th>
<th>High-Range Water Reducer b (Type F or G) gm/kg</th>
<th>Calcium Nitrite c kg/m³</th>
<th>Other Admixtures d</th>
<th>Required Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Non aggressive: Indoor or non aggressive outdoor</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.45 max</td>
<td>0</td>
<td>0</td>
<td>–</td>
<td>12.4.2</td>
</tr>
<tr>
<td>B</td>
<td>Aggressive: Subject to wet/dry cycles, marine environment,</td>
<td>100</td>
<td>0 min 25 max</td>
<td>0 min 55 max</td>
<td>0 min 15 max</td>
<td>0.45 max</td>
<td>0 min 29 max</td>
<td>0 min 25 max</td>
<td>As per Manufacturers recommendation</td>
<td>12.4.5.3</td>
</tr>
<tr>
<td>C</td>
<td>Aggressive or non-aggressive</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.45 max</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>See Note e</td>
</tr>
<tr>
<td>D special</td>
<td>Determined by the Specifying Designer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.4.5.3</td>
</tr>
</tbody>
</table>

**Notes:**

a: percent of cement substitute.
b: type D and E admixtures may be permitted with approval of the Designer.
c: Alternate corrosion inhibitors may be used.
d: other Admixtures such as anti-bleed admixtures, pumping aids, and air entraining agents.
e: No testing is required if material is prepackaged and the Manufacturer has conducted performance testing.
### Table 12.2: Grout Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Value</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Chloride Ions</td>
<td>Max. 0.08% by weight of</td>
<td>ASTM C 1152/C 1152M</td>
</tr>
<tr>
<td></td>
<td>cementitious material</td>
<td></td>
</tr>
<tr>
<td>Fine Aggregate (if utilized)</td>
<td>Max. Size &lt;No. 50 Sieve</td>
<td>ASTM C 33</td>
</tr>
<tr>
<td>Volume Change at 28 days</td>
<td>0.0% to +0.2% at 24 h and 28</td>
<td>ASTM C 1090*</td>
</tr>
<tr>
<td>days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expansion</td>
<td>≤ 2.0% for up to 3 h</td>
<td>ASTM C 940</td>
</tr>
<tr>
<td>Compressive Strength 28 days (average of 3 cubes)</td>
<td>≥ 40 Mpa</td>
<td>ASTM C 942</td>
</tr>
<tr>
<td>Initial Set of Grout</td>
<td>Min. 3 h</td>
<td>ASTM C 953</td>
</tr>
<tr>
<td></td>
<td>Max. 12 h</td>
<td></td>
</tr>
<tr>
<td>Fluidity Test**</td>
<td>Min. 11 s</td>
<td>ASTM C 939</td>
</tr>
<tr>
<td>Efflux Time from Flow Cone</td>
<td>Max. 30 s or</td>
<td>ASTM C 939***</td>
</tr>
<tr>
<td>Immediately after Mixing</td>
<td>Min. 9 s</td>
<td></td>
</tr>
<tr>
<td>30 min after Mixing with</td>
<td>Max. 20 s</td>
<td></td>
</tr>
<tr>
<td>Remixing for 30 s</td>
<td>Max. 30 s or</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Max. 30 s</td>
<td></td>
</tr>
<tr>
<td>Bleeding at 3 h</td>
<td>Max. 0.0%</td>
<td>ASTM C 940****</td>
</tr>
<tr>
<td>Permeability at 28 days</td>
<td>Max. 2500 coulombs at 30</td>
<td>AASHTO T 277 (ASTM</td>
</tr>
<tr>
<td></td>
<td>volts for 6 h</td>
<td>C 1202)</td>
</tr>
</tbody>
</table>

*Modify ASTM C 1090 to include verification at both 24 h and 28 days.

** Adjustments to flow rates will be achieved by strict compliance with the Manufacturer’s recommendations.

***Grout fluidity shall meet either the standard ASTM C 939 flow cone test or the modified test described herein.

Modify the ASTM C 939 test by filling the cone to the top instead of to the standard level. The efflux time is the time to fill a 1 L container placed directly under the flow cone.

****Modify ASTM C 940 to conform with the wick induced bleed test described below:

a. Condition dry ingredients, mixing water, pre-stressing strand and test apparatus overnight at 21 to 25°C.

b. Insert 800 ml of mixed conditioned grout with conditioned water into the 1000 mL graduated cylinder. Mark the level of the top of the grout.

c. Wrap the strand with 5 cm. wide duct or electrical tape at each end prior to cutting to avoid splaying of the wires when it is cut.

Degrease (with acetone or hexane solvent) and wire brush to remove any surface rust on the strand before temperature conditioning. Insert completely a 510 mm length of conditioned, cleaned, ASTM A 416/ A 416M seven wire strand 13 mm diameter into the 1000 mL graduated cylinder. Center and fasten the strand so it remains essentially parallel to the vertical axis of the cylinder (possibly using a centralizer). Mark the level of the top of the grout.

d. Store the mixed grout at the temperature range listed above in (a).

e. Measure the level of the bleed water every 15 min for the first hour and hourly afterward for 2 hours

f. Calculate the bleed water, if any, at the end of the 3-h test period and the resulting expansion per the procedures outlined in ASTM C 940, with the quantity of bleed water expressed as a percent of the initial grout volume. Note if the bleed water remains above or below the top of the grout.
12.4.3. Ducts

12.4.3.1. General

Ducts used to provide holes or voids in the concrete for the placement of post-tensioned bonded tendons may be either formed with removable cores or may consist of rigid or semi-rigid ducts which are cast into the concrete.

Ducts formed with removable cores shall be formed with no constrictions that would tend to block the passage of grout. All coring materials shall be removed.

Ducts formed by sheath left in place shall be a type that will not permit the intrusion of cement paste. They shall transfer bond stresses as required and shall retain shape under the weight of the concrete and shall have sufficient strength to maintain their correct alignment without visible wobble during placement of concrete.

12.4.3.2. Metal Ducts

Sheathing for ducts shall be metal, except as provided herein. Such ducts shall be galvanized ferrous metal and shall be fabricated with either welded or interlocked seams. Galvanizing of welded seams will not be required. Rigid ducts shall have smooth inner walls and shall be capable of being curved to the proper configuration without crimping or flattening. Semi-rigid ducts shall be corrugated and, when tendons are to be inserted after the concrete has been placed, their minimum wall thickness shall be as follows: 0.45 mm for ducts less than or equal to 66.7 mm diameter, 0.6 mm for ducts greater than 66.7 mm diameter. When bar tendons are preassembled with such ducts, the duct thickness shall not be less than 0.25 mm.

12.4.3.3. Plastic Ducts

For locations in saltwater environment or exposure to deicing chemicals, plastic duct material shall be considered and is recommended.

Corrugated plastic duct to be completely embedded in concrete shall be constructed from either polyethylene or polypropylene. The minimum acceptable radius of curvature shall be established by the duct supplier according to standard test methods. The duct shall have a thickness as shown in Table 12.3. Ducts shall have a white coating on the outside or shall be of white material with ultraviolet stabilizers added. Polyethylene duct shall be fabricated from resins meeting or exceeding the requirements of ASTM D 3350 with a cell classification of 345464A. Polypropylene duct shall be fabricated from resins meeting or exceeding the requirements of ASTM D 4101 with a cell classification range of PP0340BI4541 to PP0340B67884. Use resin containing antioxidant(s) with a minimum Oxidation Induction Time (OIT) according to ASTM D 3895 of not less than 20 min. The OIT test shall be performed on samples taken from the finished product.
Table 12.3: Ducts Thickness

<table>
<thead>
<tr>
<th>Duct Shape</th>
<th>Duct Diameter (mm)</th>
<th>Duct Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>any size</td>
<td>2.0</td>
</tr>
<tr>
<td>Round</td>
<td>23</td>
<td>2.0</td>
</tr>
<tr>
<td>Round</td>
<td>60</td>
<td>2.0</td>
</tr>
<tr>
<td>Round</td>
<td>75</td>
<td>2.5</td>
</tr>
<tr>
<td>Round</td>
<td>85</td>
<td>2.5</td>
</tr>
<tr>
<td>Round</td>
<td>100</td>
<td>3.0</td>
</tr>
<tr>
<td>Round</td>
<td>115</td>
<td>3.5</td>
</tr>
<tr>
<td>Round</td>
<td>130</td>
<td>4.0</td>
</tr>
<tr>
<td>Round</td>
<td>145</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Rigid smooth black polyethylene ducts for use where the tendon is not embedded in concrete shall be rigid pipe manufactured from 100 percent virgin polyethylene resin meeting the requirements of ASTM D 3350 with a minimum cell class of 344464C. A resin containing antioxidant(s) with a minimum oxidation induction time (OIT) according to ASTM D 3895 of not less than 40 min shall be used. The OIT test shall be performed on samples take from the finished product. The duct shall be manufactured with a dimensional ratio (DR) of 17.0 as established by either ASTM D 3350 or ASTM F 714 as appropriate for the manufacturing process used.

12.4.3.4. Duct Area

The provisions of Article 5.4.6.2, "Size of Ducts" of the (MA-100-D-V1/2), shall apply.

12.4.3.5. Duct Fittings

Coupling and transition fittings for ducts formed by sheathing shall be of either ferrous metal polyolefin (polyethylene or polypropylene), and shall be air and watertight and of sufficient strength to prevent distortion or displacement of the ducts during concrete placement and/or tendon grouting.

All ducts or anchorage assemblies shall be provided with pipes or other suitable connections at each end of the duct for the injection of grout after pre-stressing. As specified in Article 12.5.3.2.2, "Duct Inlets and Outlets," ducts shall also be provided with ports for venting or grouting at high points and for draining at intermediate low points.

Vent and drain pipes shall be at least 20 mm diameter for strand and at least 12 mm diameter for single-bar tendons and three or four strand flat duct tendons. Connection to ducts shall be made with metallic or plastic structural fasteners. The vents and drains shall be mortar tight, taped as necessary, and constructed with either mechanical or shrink wrap connections. Vents and drains shall provide means for injection of grout through the vents and for sealing to prevent leakage of grout.

12.5. Construction

12.5.1. General Tensioning Requirements

Tensioning may be accomplished by Pretensioning, Post-tensioning, or the combined methods; as specified in the contract documents, or on the approved working drawings, or approved in writing by the Engineer.
Pre-stressing steel shall be tensioned by hydraulic jacks so as to produce the forces shown in the contract documents or on the approved working drawing with appropriate allowances for all losses. Losses to be provided for shall be as specified in Article 5.9.5, "Loss of Prestress," of the (MA-100-D-V1/2).

For post-tensioned work, the losses shall also include the anchor set loss appropriate for the anchorage system employed.

For pre-tensioned members, the strand stress prior to seating (jacking stress) shall not exceed eighty percent (80%) of the minimum ultimate tensile strength of the pre-stressing steel \( (0.8 f_{p}^{u}) \). This allowable stress, which slightly exceeds the values allowed in (MA-100-D-V1/2), may be permitted to offset seating losses and to accommodate compensation for temperature differences specified in Article 12.5.2.1.

During stressing of strand, individual wire failures may be accepted by the Engineer, provided not more than one wire in any strand is broken and the area of broken wires does not exceed two percent of the total area of the pre-stressing steel in the member.

### 12.5.1.1. Concrete Strength

Pre-stressing forces shall not be applied or transferred to the concrete until the concrete has attained the strength specified for initial stressing. In addition, cast-in-place concrete for other than segmentally constructed bridges shall not be post-tensioned until at least ten days after the last concrete has been placed in the member to be post-tensioned.

### 12.5.1.2. Pre-stressing Equipment

Hydraulic jacks used to stress tendons shall be capable of providing and sustaining the necessary forces and shall be equipped with either a pressure gauge or a load cell for determining the jacking stress. The jacking system shall provide an independent means by which the tendon elongation can be measured. The pressure gauge shall have an accurately reading dial at least 150 mm in diameter or a digital display, and each jack and its gage shall be calibrated as a unit with the cylinder extension in the approximate position that it will be at final jacking force, and shall be accompanied by a certified calibration chart or curve. The load cell shall be calibrated and shall be provided with an indicator by means of which the pre-stressing force in the tendon may be determined. The range of the load cell shall be such that the lower ten percent of the Manufacturer's rated capacity will not be used in determining the jacking stress. When approved by the Engineer, calibrated proving rings may be used in lieu of load cells.

Recalibration of gauges shall be repeated at least annually and whenever gauge pressures and elongations indicate materially different stresses.

Only oxygen flame or mechanical cutting devices shall be used to cut strand after installation in the member or after stressing. Electric arc welders shall not be used.

### 12.5.1.3. Sequence of Stressing

When the sequence of stressing individual tendons is not specified in the contract documents or on the approved working drawings, the stressing of post-tensioning tendons and the release of pre-tensioned tendons shall be done in a sequence that produces a minimum of eccentric force in the member.
12.5.1.4. Measurement of Stress

A record of gauge pressures and tendon elongations for each tendon shall be provided by the Contractor for review and approval by the Engineer. Elongations shall be measured to an accuracy of 1.5 mm. Stressing tails of post-tensioned tendons shall not be cut off until the stressing records have been approved.

The stress in tendons during tensioning shall be determined by the gage or load-cell readings and shall be verified with the measured elongations. Calculations of anticipated elongations shall utilize the modulus of elasticity, based on nominal area, as furnished by the Manufacturer for the lot of steel being tensioned, or as determined by a bench test of strands used in the work.

All tendons shall be tensioned to a preliminary force as necessary to eliminate any take-up in the tensioning system before elongation readings are started. This preliminary force shall be between 5 and 25 percent of the final jacking force. The initial force shall be measured by a dynamometer or by other approved method, so that its amount can be used as a check against elongation as computed and as measured. Each strand shall be marked prior to final stressing to permit measurement of elongation and to ensure that all anchor wedges set properly.

It is anticipated that there may be discrepancy in indicated stress between jack gage pressure and elongation. In such event, the load used as indicated by the gage pressure shall produce a slight overstress rather than understress. When a discrepancy between gage pressure and elongation of more than five percent in tendons over 15 m long or seven percent in tendons of 15 m or less in length occurs, the entire operation shall be carefully checked and the source of error determined and corrected before proceeding further. When provisional ducts are provided for addition of pre-stressing force in event of an apparent force deficiency in tendons over 15 m long, the discrepancy between the force indicated by gage pressure and elongation may be increased to seven percent before investigation into the source of the error.

12.5.2. Pre-Tensioned Members

12.5.2.1. Pretensioning Requirements

Stressing shall be accomplished by either single-strand stressing or multiple-strand stressing. The amount of stress to be given to each strand shall be as shown in the contract documents or on the approved working drawings.

All strands to be stressed in a group (multiple-strand stressing) shall be brought to a uniform initial tension prior to being given their full Pretensioning. The amount of the initial tensioning force shall be within the range specified in Article 12.5.1.4 and shall be the minimum required to eliminate all slack and to equalize the stresses in the tendons as determined by the Engineer. The amount of this force will be influenced by the length of the casting bed and the size and number of tendons in the group to be tensioned.

Draped pretension tendons shall either be tensioned partially by jacking at the end of the bed and partially by uplifting or depressing tendons, or they shall be tensioned entirely by jacking, with the tendons being held in their draped positions by means of rollers, pins, or other approved methods during the jacking operation.

Approved low-friction devices shall be used at all points of change in slope of tendon trajectory when tensioning draped pretension strands, regardless of the tensioning method used.
If the load for a draped strand, as determined by elongation measurements, is more than five percent less than that indicated by the jack gages, the strand shall be tensioned from both ends of the bed, and the load as computed from the sum of elongation at both ends shall agree within five percent of that indicated by the jack gages.

When ordered by the Engineer, pre-stressing steel strands in pretension members, if tensioned individually, shall be checked by the Contractor for loss of Prestress not more than 3 hours prior to placing concrete for the members. The method and equipment for checking the loss of Prestress shall be subject to approval by the Engineer. All strands that show a loss of Prestress in excess of three percent shall be retensioned to the original computed jacking stress.

Stress on all strands shall be maintained between anchorages until the concrete has reached the compressive strength required at time of transfer of stress to concrete.

When pre-stressing steel in pretensioned members is tensioned at a temperature more than fourteen degree Celsius (14°C) lower than the estimated temperature of the concrete and the pre-stressing steel at the time of initial set of the concrete, the calculated elongation of the pre-stressing steel shall be increased to compensate for the loss in stress due to the change in temperature, but in no case shall the jacking stress exceed eighty percent (80%) of the specified minimum ultimate tensile strength of the pre-stressing steel.

Strand splicing methods and devices shall be approved by the Engineer. When single-strand jacking is used, only one splice per strand will be permitted. When multi-strand jacking is used, either all strands shall be spliced or no more than ten percent of the strands shall be spliced. When more than strand are spliced, the splice location should be staggered. Spliced strands shall be similar in physical properties, from the same source, and shall have the same "twist" or "lay." All splices shall be located outside of the prestressed units.

Side and flange forms that restrain deflection shall be removed before release of Pretensioning reinforcement.

Except when otherwise shown in the contract documents, all pretensioned pre-stressing strands shall be cut off flush with the end of the member, and the exposed ends of the strand and a 25 mm strip of adjoining concrete shall be cleaned and painted. Cleaning shall be by wire brushing or abrasive blast cleaning to remove all dirt and residue that is not firmly bonded to the metal or concrete surfaces. The surfaces shall be coated with one thick coat of zinc-rich paint conforming to the requirements of U.S. Military Specification MIL-P-2444 1/20. The paint shall be thoroughly mixed at the time of application, and shall be worked into any voids in the strands.

12.5.2.2. Placement of Prestressing Steel

Pre-stressing steel placed in the stressing bed shall be protected from corrosion if the stressing bed is to be exposed to weather for more than 36 hours before encasement in concrete.

All strands shall be freed of kinks or twists. Pre-stressing steel shall be held accurately in position and tension according to Article 12.5. Strands shall not be allowed to unwind more than one turn. The record of the jacking force and elongation measurements shall be kept after the strands are tensioned to twenty percent (20%) of final jacking force.

The pre-stressing steel shall be tensioned to the required stress. The Contractor shall include in elongation computations strand anchorage slippage, splice slippage, in place
horizontal movement of the structural member during pre-stressing operations, and pre-
stressing steel temperature changes between the time of tensioning and the time when the concrete takes its initial set. All computations must be prepared by a professional Engineer.

The Contractor shall maintain the prestress bed forms, strands, and reinforcement bar temperature within 15 °C of the temperature of the concrete to be placed in the forms. Strands shall be supported with rollers at points of direction change when strands are tensioned in a draped position. Free-running rollers with minimal friction shall be used. Initially, when strands are tensioned and then pulled into the draped position, the Contractor shall tension to no more than the required tension minus the increased tension due to forcing the strand to a draped profile. If the load in a draped strand at the dead end, as determined by elongation measurements, is less than ninety-five percent (95%) of the jack load, the strand shall be tensioned from both ends of the bed. The load shall be made, as computed from the sum of elongations produced by jacking at both ends, agree within five percent (5%) of the jack load.

Within 3 hours before placing concrete, the tension on the pre-stressing strands shall be checked. The method and equipment for checking the loss of prestress shall be subject to approval by the Engineer. If strands are tensioned individually, each strand shall be checked for loss of prestress. The Contractor shall re-tension to the original computed jacking stress all strands that show a loss of prestress in excess of three percent (3%). If strands are tensioned in a group, the entire group for total loss of prestress shall be checked. The Contractor shall release and re-tension the entire group if the total prestress shows a loss in excess of three percent (3%) or if any individual strand appears significantly different from the rest of the strands in the group.

12.5.2.3. Releasing Steel

The prestress load shall be released to the concrete after the concrete has attained its required release compressive strength. The concrete shall not be exposed to temperatures below freezing for at least 7 days after casting. The strands shall be cut or released such that lateral eccentricity of the prestress force is minimized. Pre-stressing steel shall be cut off flush with the end of the member.

12.5.3. Post-Tensioned Members

12.5.3.1. Post-Tensioning Requirements

Prior to post-tensioning any member, the Contractor shall demonstrate to the satisfaction of the Engineer that the pre-stressing steel is free and unbonded in the duct.

All strands in each tendon, except for those in flat ducts with not more than four strands, shall be stressed simultaneously with a multi-strand jack.

Tensioning shall be accomplished so as to provide the forces and elongations specified in Article 12.5.4.1.

Except as provided herein or when specified in the contract documents or on the approved working drawings, tendons in continuous post-tensioned members shall be tensioned by jacking at each end of the tendon. For straight tendons and when one end stressing is shown in the contract documents, tensioning may be performed by jacking from one-end or both ends of the tendon at the option of the Contractor.
12.5.3.2. Placement of Ducts

1. General

Ducts shall be rigidly supported at the proper locations in the forms by ties to reinforcing steel which are adequate to prevent displacement during concrete placement. Supplementary support bars shall be used where needed to maintain proper alignment of the duct. Hold-down ties to the forms shall be used when the buoyancy of the ducts in the fluid concrete would lift the reinforcing steel.

Polyethylene duct and metal duct for longitudinal or transverse post-tensioning in the flanges shall be supported at intervals not to exceed 0.6 m. Polyethylene duct in webs for longitudinal post-tensioning shall be tied to stirrups at interval not to exceed 600 mm and metal duct for longitudinal post-tensioning in web shall be tied to stirrups at interval not to exceed 1.2 m.

Joints between sections of duct shall be coupled with positive connections which do not result in angle changes at the joints and will prevent the intrusion of cement paste.

After placing of ducts, reinforcement and forming is complete, an inspection shall be made to locate possible duct damage.

All unintentional holes or openings in the duct must be repaired prior to concrete placing.

Grout openings and vents must be securely anchored to the duct and to either the forms or to reinforcing steel to prevent displacement during concrete placing operations.

After installation in the forms, the ends of ducts shall at all times be covered as necessary to prevent the entry of water or debris.

During concrete placement for precast segments, mandrels shall be used as stiffeners in each duct and shall extend throughout the length of the segment being cast and at least 0.6 m into the corresponding duct of the previously cast segment. The mandrels shall be of sufficient rigidity to maintain the duct geometry within the tolerances shown in Table 12.4.

<table>
<thead>
<tr>
<th>Tolerances</th>
<th>Vertical position (mm)</th>
<th>Lateral position (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal tendons in slabs or in slab regions of larger members</td>
<td>±6</td>
<td>±12</td>
</tr>
<tr>
<td>Longitudinal draped superstructure tendons in webs Tendon over supports or in middle third of span</td>
<td>±6</td>
<td>±6</td>
</tr>
<tr>
<td>Tendon in middle half of web depth</td>
<td>±12</td>
<td>±6</td>
</tr>
<tr>
<td>Longitudinal, generally horizontal superstructure tendons usually in top or bottom of member</td>
<td>±6</td>
<td>±6</td>
</tr>
<tr>
<td>Horizontal tendons in substructures and foundations</td>
<td>±12</td>
<td>±12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Longitudinal position (mm)</th>
<th>Transverse position (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical tendons in webs</td>
<td>±6</td>
</tr>
<tr>
<td>Vertical tendons in pier shafts</td>
<td>±6</td>
</tr>
</tbody>
</table>
Additionally, the following shall apply:

- In all other cases, locate tendons within ±6 mm in any direction.
- Entrance and exit angles of tendon paths at anchorages and/or at faces of concrete shall be within ±3 degrees of desired angle measured in any direction and any deviations in the alignment are accomplished with smooth transitions without any kinks.
- Angle changes at duct joints shall not be greater than ±3 degrees in any direction and must be accomplished with smooth transitions without any kinks.
- Locate anchorages within ±6 mm of desired position laterally and ±25 mm along the tendon except that minimum cover requirements shall be maintained.
- Position anchorage confinement reinforcement in the form of spirals, multiple V-shaped bars or links, to be properly centered around the duct and to start within 12 mm of the back of the main anchor plate.
- If conflicts exist between the reinforcement and post-tensioning duct, position the post-tensioning duct and adjust the reinforcement locally with the Engineer's approval.

2. Duct Inlets and Outlets

All ducts for continuous structures shall be supplied with outlets at the high and low points of the duct profile, except where the profile changes are small, as in continuous slabs, and at additional locations as specified in the contract documents. Low-point outlets shall remain open until grouting is started.

3. Proving of Post-Tensioning Ducts

Upon completion of concrete placement the contractor shall prove that post-tensioning ducts are free and clear of any objections or damage and are able to accept the intended post-tensioning tendons by passing a torpedo through the duct. The torpedo shall have the same cross-sectional shape as the duct, and 6 mm smaller all around than the clear nominal inside dimensions of the duct. No deductions shall be made to the torpedo section dimensions for tolerances allowed in the manufacture or fixing of the ducts. For straight ducts, a torpedo at least 0.6 m long shall be used. For curved ducts, the length shall be determined so that when both ends touch the outermost wall of the duct, the torpedo is 6 mm clear of the innermost wall. If the torpedo will not travel completely through the duct, the Engineer shall reject the member, unless workable repairs, the torpedo shall pass through the duct easily, by hand, without resorting to excessive effort or mechanical assistance.

4. Duct Pressure Field Test

Before stressing and grouting internal or external tendons, install all grout caps, inlets and outlets and test the duct with compressed air to determine if duct connections require repair. In the presence of the Engineer, pressurize the duct to 345 kPa and lock-off the outside air source. Record pressure loss for 1 min. A pressure loss of 170 kPa is acceptable for ducts, having a length of equal to or less than 45 m and a pressure loss of 100 kPa is acceptable for ducts longer than 45 m. If the pressure loss exceeds the allowable, repair leaking connections using methods approved by the Engineer and retest.
12.5.3.3. Placement of Concrete

Where the end of a post-tensioned assembly will not be covered by concrete, recess the anchoring devices so that the ends of the pre-stressing steel and all parts of the anchoring devices are at least 51 mm inside the end surface of the members.

Before placing concrete, demonstrate that all ducts are unobstructed. Immediately after concrete placement, blow out the metal conduit with compressed, oil-free air to break-up and remove all mortar in the conduit before it hardens. Approximately 24 hours after the concrete placement, flush the metal conduits with water containing lime (calcium oxide) or slaked lime (calcium hydroxide) in the amount of 1.13 kN/m$^3$. Blow the water out with compressed, oil-free air.

For post-tensioned members that are to be steam cured, do not install pre-stressing steel until curing is complete.

12.5.3.4. Placement of Post-Tensioning Steel

All pre-stressing steel preassembled in ducts and installed prior to the placement of concrete shall be accurately placed and held in position during concrete placement.

When the pre-stressing steel is installed after the concrete has been placed, the Contractor shall demonstrate to the satisfaction of the Engineer that the ducts are free of water and debris immediately prior to installation of the steel. The total number of strands in an individual tendon may be pulled into the duct as a unit, or the individual strand may be pulled or pushed through the duct.

Anchorage devices or block-out templates for anchorages shall be set and held so that their axis coincides with the axis of the tendon and anchor plates are normal in all directions to the tendon.

The pre-stressing steel shall be distributed so that the force in each girder stem is equal or as required by the plans, except as provided herein. For box girders with more than two girder stems, at the Contractor's option, the pre-stressing force may vary up to one percent (1%) from the theoretical required force per girder stem provided the required total force in the superstructure is obtained and the force is distributed symmetrically about the center line of the typical section.

1. Protection of Steel after Installation

Pre-stressing steel used in post tensioned concrete members that is not grouted within the time limit specified below, shall be continuously protected against rust or other corrosion by means of a corrosion inhibitor placed in the ducts or directly applied to the steel. The pre-stressing steel shall be so protected until grouted or encased in concrete. Pre-stressing steel installed and tensioned in members after placing and curing of the concrete and grouted within the time limit specified below will not require the use of a corrosion inhibitor described herein and rust which may form during the interval between tendon installation and grouting will not be cause for rejection of the steel.

The permissible interval between tendon installation and grouting without use of a corrosion inhibitor for various exposure conditions shall be as follows:

<table>
<thead>
<tr>
<th>Exposure Conditions</th>
<th>Time Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Damp Atmosphere or over Saltwater (Humidity &gt; 70%)</td>
<td>7 Days</td>
</tr>
<tr>
<td>Moderate Atmosphere (Humidity from 40% to 70%)</td>
<td>15 Days</td>
</tr>
</tbody>
</table>
Very Dry Atmosphere (Humidity < 40%)

After tendons are placed in ducts, the openings at the ends of the ducts shall be sealed to prevent entry of moisture.

When steam curing is used, steel for post-tensioning shall not be installed until the steam curing is completed.

Such tendons shall be protected against corrosion by means of a corrosion inhibitor placed in the ducts or on the steel, or shall be stressed and grouted within seven days after steam curing.

Whenever electric welding is performed on or near members containing pre-stressing steel, the welding ground shall be attached directly to the steel being welded. All pre-stressing steel and hardware shall be protected from weld spatter or other damage.

2. Protection of Tendon

Within four hours after stressing and prior to grouting, tendons shall be protected against corrosion or harmful effects of debris by temporarily plugging or sealing all openings and vents; cleaning rust and other debris from all metal surfaces which will be covered by the grout cap; and placing the grout cap, including a seal, over the wedge plate until the tendon is grouted.

12.5.3.5. Placement of Anchorage

The contractor is responsible for the proper placement of all materials according to the design documents of the engineer of record and the requirements stipulated by the anchorage device supplier. The Contractor shall exercise all due care and attention in the placement of anchorage hardware, reinforcement, concrete, and consolidation of concrete in anchorage zones. Modifications to the local zone details verified under provisions of Article 12.4.1.2.3 and Article 5.10.9.7.3 (MA-100-D-V1/2) shall be approved by both the Professional Engineer and the anchorage device supplier.

12.5.3.6. Record of Stressing Operation

A record of the following post-tensioning operations shall be kept for each tendon installed:

- Project name, number,
- Contractor and/or subcontractor,
- Tendon location, size and type,
- Date tendon was first installed in ducts,
- Coil/reel number for strands or wires and heat number for bars and wire,
- Assumed and actual cross-sectional area,
- Assumed and actual modulus of elasticity,
- Date stressed,
- Jack and gage numbers per end of tendon,
- Required jacking force,
- Gage pressures,
- Elongations (anticipated and actual),
• Anchor sets (anticipated and actual),
• Stressing sequence (i.e., tendons before and after this tendon),
• Stressing mode (one end/two ends/simultaneous),
• Witnesses to stressing operation (Contractor and Inspector),
• Date grouted, days from stressing to grouting, grouting pressure applied, and injection end,
• Record any other relevant information including pourback and bitumastic installation dates,

The Engineer shall be provided with a complete copy of all stressing operations, and the jack calibration forms.

12.5.4. Identification and Testing

All wire, strand, or bars to be shipped to the site shall be assigned a lot number and tagged for identification purposes. Anchorage assemblies to be shipped shall be likewise identified.

Each lot of wire or bars and each reel of strand reinforcement shall be accompanied by a manufacturer's certificate of compliance, a mill certificate, and a test report. The mill certificate and test report shall include:

- Chemical composition (not required for strand),
- Cross sectional area,
- Yield and ultimate strengths,
- Elongation at rupture,
- Modulus of elasticity, and
- Stress strain curve for the actual pre-stressing steel intended for use.

All values certified shall be based on test values and nominal sectional areas of the material being certified.

The Contractor shall furnish to the Engineer for verification testing the samples described in the following sub articles selected from each lot. If ordered by the Engineer, the selection of samples shall be made at the manufacturer's plant by the Inspector.

All samples submitted shall be representative of the lot to be furnished and, in the case of wire or strand, shall be taken from the same master roll.

The actual strength of the pre-stressing steel shall not be less than specified by the applicable ASTM Standard, and shall be determined by tests of representative samples of the tendon material in conformance with ASTM Standards.

All of the materials specified for testing shall be furnished free of cost and shall be delivered in time for tests to be made well in advance of anticipated time of use.

12.5.4.1. Pretensioning Tendons

For pre-tensioned strands, one sample at least 1.5 m long shall be furnished in accordance with the requirements of Paragraph 9.1 of AASHTO M 203M/M 203 (ASTM A 416/A 416M).
12.5.4.2. Post-Tensioning Tendons

The following lengths shall be furnished for each 18,000 kg, or portion thereof, lot of material used in the work:

- For wires not requiring heading-sufficient length to make up one parallel-lay cable 1.5 m long consisting of the same number of wires as the cable to be furnished.
- For strand to be furnished with fittings 1.5 m between near ends of fittings.
- For bars to be furnished with threaded ends and nuts 1.5 m between threads at ends.

12.5.4.3. Anchorage Assemblies and Couplers

The Contractor shall furnish for testing one specimen of each size of pre-stressing tendon, including couplings, at the selected type, with end fittings and anchorage assembly attached, for strength tests only. These specimens shall be 1.5 m in clear length, measured between ends of fittings. If the results of the test indicate the necessity of check tests, additional specimens shall be furnished without cost.

When dynamic testing is required, the Contractor shall perform the testing and shall furnish certified copies of test results which indicate conformance with the specified requirements prior to installation of anchorages or couplers. The cost of such testing shall be borne by the Contractor.

For pre-stressing systems previously tested and approved on projects having the same tendon configuration, the Engineer may not require complete tendon samples provided there is no change in the material, design, or details previously approved. Shop drawings or pre-stressing details shall identify the project on which approval was obtained; otherwise testing shall be conducted.

12.5.5. Protection of Pre-stressing Steel

All pre-stressing steel shall be protected against physical damage and rust or other results of corrosion at all times from manufacture to grouting. Pre-stressing steel shall also be free of deleterious material such as grease, oil, wax, or paint. Pre-stressing steel that has sustained physical damage at any time shall be rejected. The development of pitting or other results of corrosion, other than rust stain shall be cause for rejection.

Pre-stressing steel shall be packaged in containers or shipping forms for the protection of the strand against physical damage and corrosion during shipping and storage. A corrosion inhibitor which prevents rust or other results of corrosion shall be placed in the package or form, or shall be incorporated in a corrosion inhibitor carrier type packaging material, or when permitted by the Engineer, may be applied directly to the steel. The corrosion inhibitor shall have no deleterious effect on the steel or concrete or bond strength of steel to concrete or grout. Packaging or forms damaged from any cause shall be immediately replaced or restored to original condition.

The shipping package or form shall be clearly marked with a statement that the package contains high-strength pre-stressing steel, and the type of corrosion inhibitor used, including the date packaged.

All anchorages, end fittings, couplers, and exposed tendons, which will not be encased in concrete or grout in the completed work, shall be permanently protected against corrosion.

12.5.6. Corrosion Inhibitor

Corrosion inhibitor shall consist of a vapor phase inhibitor (VPI) powder conforming to the provision of Federal Specification MIL-P-3420F-87 or as otherwise
approved by the Engineer. When approved, water soluble oil may be used on tendons as a corrosion inhibitor.

12.5.7. Grouting

12.5.7.1. General

When the post-tensioning method is used, the pre-stressing steel shall be provided with permanent protection and shall be bonded to the concrete by completely filling the void space between the duct and the tendon with grout. Grout should be injected from low points pumping toward the high-point vent. For segmental, span-by-span construction, grout shall be injected through a grout inlet at mid span.

All grouting operations shall be carried out by experienced superintendents and foremen that have received instructional training and have at least 3 years of experience on previous projects involving grouting of similar type and magnitude.

A grouting operation plan shall be submitted for approval at least 45 days in advance of any scheduled grouting operations. Written approval of the grouting operation plan by the Engineer shall be required before any grouting of the permanent tendons in the structure takes place.

At a minimum, the following items shall be provided in the grouting operation plan:
- Provide names, and proof of training and experience records for the grouting crew and the crew supervisor in conformance with this Specification;
- Type, quantity, and brand of materials used in grouting including all required certifications.
- Type of equipment furnished, including capacity in relation to demand and working condition, as well as back-up equipment and spare parts;
- General grouting procedure;
- Duct pressure test and repair procedures;
- Method to be used to control the rate of flow within ducts;
- Theoretical grout volume calculations;
- Mixing and pumping procedures;
- Direction of grouting;
- Sequence of use of the inlets and outlet pipes;
- Procedures for handling blockages; and
- Procedures for possible post grouting repair.

Before grouting operations begin, a joint meeting of the Contractor, grouting crew and the Engineer shall be conducted. At the meeting, the grouting operation plan, required testing, corrective procedures, and any other relevant issues shall be discussed.

12.5.7.2. Preparation of Ducts

Each duct shall be air pressure tested prior to the installation of the pre-stressing steel into the ducts. If leaks are indicated during the test, the duct shall be repaired to eliminate the leakage or minimize the consequences of the leakage.

All ducts shall be clean and free of deleterious materials that would impair bonding or interfere with grouting procedures.
Ducts with concrete walls (cored ducts) shall be flushed to ensure that the concrete is thoroughly wetted. Metal ducts shall be flushed if necessary to remove deleterious material.

Water used for flushing ducts may contain slack lime (calcium hydroxide) or quicklime (calcium oxide) in the amount of 0.012 kg/L.

After flushing, all water shall be blown out of the duct with oil-free compressed air.

12.5.7.3. Equipment

The grouting equipment for Type B grout material shall include a high-speed shear mixer capable of continuous mechanical mixing which will produce a grout free of lumps and undispersed cement, a grout pump, and stand-by flushing equipment with water supply. The equipment shall be able to pump the mixed grout in a manner which will comply with all requirements.

Accessory equipment which will provide for accurate solid and liquid measures shall be provided to batch all materials.

The pump shall be a positive displacement type and be able to produce an outlet pressure of at least 1 MPa. The pump should have seals adequate to prevent introduction of oil, air, or other foreign substance into the grout, and to prevent loss of grout or water.

A pressure gage having a full-scale reading of no greater than 2 MPa shall be placed at some point in the grout line between the pump outlet and the duct inlet.

The grouting equipment shall contain a screen having clear openings of 3.35 mm maximum size to screen the grout prior to its introduction into the grout pump. If a grout with a thixotropic additive is used, a screen opening of 4.75 mm is satisfactory. This screen shall be easily accessible for inspection and cleaning.

The grouting equipment shall utilize gravity feed to the pump inlet from a hopper attached to and directly over it. The hopper must be kept at least partially full of grout at all times during the pumping operation to prevent air from being drawn into the post-tensioning duct.

Under normal conditions, the grouting equipment shall be capable of continuously grouting the largest tendon on the project in no more than 20 min.

12.5.7.4. Mixing of Grout

Water shall be added to the mixer first, followed by cement grout.

Grout shall be mixed in accordance with the Manufacturer's instructions using a colloidal mixer to obtain homogeneous mixture. A fluidity test shall be performed on the mixed grout prior to beginning the injection process. Target flow rates as a function of mixer type used and ambient temperatures shall be obtained from the grout Manufacturer. The grouting process shall not be started until the proper grout properties have been obtained.

Mixing shall be of such duration as to obtain a uniform, thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixture. The grout shall be continuously agitated until it is pumped.

Water shall not be added to increase grout flowability which has been decreased by delayed use of the grout.

Other methods may be used to determine fluidity such as U.S. Army Corps of Engineers Method CRD C79.
12.5.7.5. Injection of Grout

All grout vents shall be opened before grouting starts.

Injection and ejection vents with positive shut-offs shall be provided. Grout shall be allowed to flow from the first injection vent until any residual flushing water or entrapped air has been removed prior to closing that vent. Remaining vents shall be closed in sequence in the same manner. A continuous flow of grout at a rate between 10 m and 15 m of duct per min shall be maintained.

The pumping pressure at the injection vent should not exceed 1 MPa. Normal operations shall be performed at approximately 0.5 MPa. If the actual grouting pressure exceeds the maximum allowed, the injection vent shall be closed and the grout shall be injected at the next vent that has been, or is ready to be closed, as long as a one-way flow is maintained. Grout shall not be injected into a succeeding vent from which grout has not yet flowed.

Grout shall be pumped through the duct and continuously wasted at the ejection vent until no visible slugs of water or air are ejected. A fluidity test shall be performed on each tendon in accordance with Article 12.4.2.3 measuring the grout fluidity from the discharge outlet. The measured grout efflux time shall not be faster than the efflux time measured at the inlet or the minimum efflux time established in Article 12.4.2.3. If the grout efflux time is not acceptable, additional grout shall be discharged from the discharge outlet. Grout efflux time shall be tested. This cycle shall be continued until acceptable grout fluidity is achieved. To ensure that the tendon remains filled with grout, the ejection and injection vents shall be closed in sequence, respectively, under pressure when the tendon duct is completely filled with grout. The positive shut-offs at the injection and ejection vents shall not be removed or vents opened until the grout has set.

12.5.7.6. Temperature Considerations

In temperatures below zero degree Celsius (0°C), ducts shall be kept free of water to avoid damage due to freezing. The temperature of the concrete shall be two degree Celsius (2°C) or higher from the time of grouting until job cured 50 mm cubes of grout reach a minimum compressive strength of 5.5 MPa. Grout shall not be above thirty-five degree Celsius (35°C) during mixing or pumping. If necessary, cool the mixing water.

12.5.7.7. Vertical Grouting

In lieu of a positive shut-off, vertical or near vertical tendon ducts for grouting shall terminate in reservoirs at the upper-most point. The reservoir shall have sufficient capacity to store excess grout bleed water. Visible grout level shall be maintained in the reservoirs. The reservoirs shall be maintained until the grout has set.

Grout shall be injected at a rate of 5 m of duct per min.

12.5.7.8. Post-Grouting Inspection

Vacuum grouting shall be used to fill any voids that expose strands discovered in the grouting process.

Where possible, all anchorages and high-point vents shall be drilled and probed 48 h after grouting, until the Engineer is assured that no bleed water or subsidence (settlement) voids exist. After the Engineer is assured that voids do not exist, only one or two anchorages per span shall be drilled and probed to ensure quality grouting. Any voids discovered should be filled immediately with the approved grout.
12.5.7.9. Finishing
The following requirements apply:
- Valves, caps and vent pipes shall not be removed or opened until the grout has set.
- The ends of vents shall be removed at least 25 mm below the concrete surface after the grout has set.
- The void shall be filled with epoxy grout. All miscellaneous material used for sealing grout caps shall be removed before carrying out further work to protect end anchorages.

12.5.7.10. Protection of End Anchorages
Permanent grout caps constructed from either stainless steel or fiber reinforced polymer shall be specified.

The following requirements apply:
- Within seven days upon completion of the grouting, the anchorage of post-tensioning bars and tendons shall be protected as indicated in the contract documents. The application of the elastomeric coating may be delayed up to 90 days after grouting. Plastic or stainless steel threaded caps shall be used to plug all grout inlets/outlets. A sand-filled epoxy grout suitable for machinery base plate shall be used to construct all pourbacks located at anchorages of expansion joints or other areas exposed to the elements.
- All laitance, grease, curing compounds, surface treatments, coatings, and oils shall be removed by grit blasting or water blasting using a minimum 70 MPa nozzle pressure. The surface shall be flushed with water and blown dry. Surfaces shall be clean, sound, and without any standing water. In case of dispute, ACI 503 shall be followed for substrate testing and a minimum of 1.2 MPa tension (pull-off value) be developed.
- Epoxy shall be mixed and applied as per Manufacturer's current standard technical guidelines. All pour-backs shall be in leak proof forms creating neat lines. The pumping of epoxy grout shall be permitted for proper installation. Forms shall be constructed to maintain a liquid head to insure intimate contact with the concrete surface. Vents shall be used as needed to provide for the escape of air to insure complete filling of the forms.
- The exposed surfaces of pour-backs or grout caps, except on transverse tendons, shall be coated with an elastomeric coating system having a thickness of 760 to 1140 µm. Concrete, grout caps or other substrates shall be structurally sound, clean, and dry. Concrete shall be a minimum of 28 days old. Laitance, grease, curing compounds, surface treatments, coatings, and oils shall be removed by grit blasting or water blasting using a minimum 70 MPa nozzle pressure to establish the anchor pattern. Surfaces shall be blown with compressed air to remove the dust or water.
- A 0.6×1.2 m concrete test block shall be constructed with a similar surface texture to the surfaces to be coated and a vertical face shall be coated with the elastomeric coating system chosen. The number of coats required to achieve a coating thickness between 760 to 1140 µm without runs and drips shall be determined. The elastomeric coating shall be mixed and applied as per Manufacturer's current standard technical specifications. Spray or roller application may be permitted; spray application is preferred. Coatings shall be applied using approved and experienced personnel with a minimum of 3 years experience applying similar polyurethane
systems. Credentials of these persons shall be submitted to the Engineer for review and consideration for approval.

12.5.7.11. Construction Traffic and Operations Causing Vibrations

For the designated period of time after grouting of a tendon begins, vibrations from all sources such as moving vehicles, jackhammers, compressors, generators, etc., that are operating within the affected bridge superstructure shall be eliminated and pile driving and soil compaction within 91 m of the affected superstructure shall not be permitted. The designated period of time shall be taken as 4 hours for prequalified anti-bleed grout and 24 hours for plain grout. The affected bridge superstructure shall be taken as that portion of the total superstructure that is 91 m up or down-station of the ends of the span in which grouting is taking place.

12.5.8. Tolerances

Members shall be produced well within the specified acceptable range. The production process shall be corrected when members approach or equal a specified limit. The Contractor shall immediately notify the Engineer of any out-of-tolerance members. Applicable dimensional tolerances shall be checked before casting and after removal from the forms. Time-dependent tolerances, such as, length, camber, and sweep, shall be rechecked within 3 days before shipment. Camber and sweep shall be checked at a time when thermal effects of sunlight are negligible such as on a cloudy day or early morning. Sweep is defined as the horizontal deviation from a straight line parallel to the centerline of the member. Camber is defined as upward deflection of the member caused by prestress. The Contractor shall check local smoothness with a 1.5 m straightedge.

The Contractor shall comply with the maximum dimensional tolerances in Table 12.5 for AASHTO girders and bulbtees, Table 12.6 for double-tees, Table 12.7 for prestressed piling, and Table 12.8 for prestressed deck panels.
### Table 12.5: Maximum Dimensional Tolerances for AASHTO Girders and Bulb-tees

<table>
<thead>
<tr>
<th></th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>(±0.8mm/m, ±25mm max.)</td>
</tr>
<tr>
<td>Width (overall)</td>
<td>(+10mm, -6mm)</td>
</tr>
<tr>
<td>Width (web)</td>
<td>(+10mm, -6mm)</td>
</tr>
<tr>
<td>Depth (overall)</td>
<td>(+13mm, -6mm)</td>
</tr>
<tr>
<td>Depth (flanges)</td>
<td>(±6mm)</td>
</tr>
<tr>
<td>Sweep</td>
<td>(1mm/m)</td>
</tr>
<tr>
<td>Variation from end squareness or skew</td>
<td>(±16mm/m, ±25mm max.)</td>
</tr>
<tr>
<td>Camber variation from design camber$^1$</td>
<td>(±1mm/m)</td>
</tr>
<tr>
<td>For spans of 24 m or less</td>
<td>(±13mm max.)</td>
</tr>
<tr>
<td>For spans more than 24 m</td>
<td>(±25mm max.)</td>
</tr>
<tr>
<td>Differential camber between adjacent members</td>
<td>(1mm/m)</td>
</tr>
<tr>
<td>Position of Strands:</td>
<td></td>
</tr>
<tr>
<td>Individual</td>
<td>(±6mm)</td>
</tr>
<tr>
<td>Bundled</td>
<td>(±13mm)</td>
</tr>
<tr>
<td>Draped strand holddown point</td>
<td>(±0.5m)</td>
</tr>
<tr>
<td>Position of plates:</td>
<td></td>
</tr>
<tr>
<td>Bearing plates</td>
<td>(±16mm)</td>
</tr>
<tr>
<td>Other plates</td>
<td>(±25mm)</td>
</tr>
<tr>
<td>Tipping and flushness of plates:</td>
<td></td>
</tr>
<tr>
<td>Bearing plates</td>
<td>(±0.5%, ±3mm max.)</td>
</tr>
<tr>
<td>Other plates</td>
<td>(±6mm)</td>
</tr>
<tr>
<td>Position of Inserts including diaphragm holes</td>
<td>(±13mm)</td>
</tr>
<tr>
<td>Position of handling devices:</td>
<td></td>
</tr>
<tr>
<td>Parallel to length</td>
<td>(±150mm)</td>
</tr>
<tr>
<td>Transverse to length</td>
<td>(±25mm)</td>
</tr>
<tr>
<td>Position of stirrups:</td>
<td></td>
</tr>
<tr>
<td>Longitudinal spacing</td>
<td>(±50mm)</td>
</tr>
<tr>
<td>Projection above top</td>
<td>(±19mm)</td>
</tr>
<tr>
<td>Local smoothness of any formed surface</td>
<td>(±3mm/1500mm)</td>
</tr>
</tbody>
</table>

*Note (1): Use this camber tolerance when a design camber is specified.*
Table 12.6: Maximum Dimensional Tolerances for Double-tees

<table>
<thead>
<tr>
<th></th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>(±0.8mm/m, ±25mm max.)</td>
</tr>
<tr>
<td>Width (overall)</td>
<td>(±6mm)</td>
</tr>
<tr>
<td>Width (webs)</td>
<td>(±3mm)</td>
</tr>
<tr>
<td>Depth (overall)</td>
<td>(±6mm)</td>
</tr>
<tr>
<td>Thickness (flanges)</td>
<td>(±6mm, -3mm)</td>
</tr>
<tr>
<td>Flange Overhang (flange edge to web edge)</td>
<td>(±6mm)</td>
</tr>
<tr>
<td>Distance between Webs</td>
<td>(±6mm)</td>
</tr>
<tr>
<td>Sweep</td>
<td>(1mm/m)</td>
</tr>
<tr>
<td>Variation from end squareness or skew</td>
<td>(±10mm/m, ±25mm max.)</td>
</tr>
<tr>
<td>Camber variation from design camber</td>
<td>(±1mm/m, ±19mm max.)</td>
</tr>
<tr>
<td>Differential camber between adjacent members</td>
<td>(1mm/m, 19mm max.)</td>
</tr>
<tr>
<td>Position of Strands:</td>
<td></td>
</tr>
<tr>
<td>Individual</td>
<td>(±6mm)</td>
</tr>
<tr>
<td>Bundled</td>
<td>(±13mm)</td>
</tr>
<tr>
<td>Draped strand holddown point</td>
<td>(±300mm)</td>
</tr>
<tr>
<td>Position of plates:</td>
<td></td>
</tr>
<tr>
<td>Bearing plates</td>
<td>(±13mm)</td>
</tr>
<tr>
<td>Other plates</td>
<td>(±25mm)</td>
</tr>
<tr>
<td>Tipping and flushness of plates:</td>
<td></td>
</tr>
<tr>
<td>Bearing plates</td>
<td>(±0.5%, ±3mm max.)</td>
</tr>
<tr>
<td>Other plates</td>
<td>(±6mm)</td>
</tr>
<tr>
<td>Position of inserts including diaphragm holes</td>
<td>(±13mm)</td>
</tr>
<tr>
<td>Position of handling devices:</td>
<td></td>
</tr>
<tr>
<td>Parallel to length</td>
<td>(±150mm)</td>
</tr>
<tr>
<td>Transverse to length</td>
<td>(±25mm)</td>
</tr>
<tr>
<td>Position of stirrups:</td>
<td></td>
</tr>
<tr>
<td>Longitudinal spacing</td>
<td>(±50mm)</td>
</tr>
<tr>
<td>Projection above top</td>
<td>(±19mm)</td>
</tr>
<tr>
<td>Local smoothness of any formed surface</td>
<td>(±3mm/1500mm)</td>
</tr>
</tbody>
</table>

Note (1): Use this camber tolerance when a design camber is specified.

Table 12.7: Maximum Dimensional Tolerances for Prestressed Concrete Piling

<table>
<thead>
<tr>
<th></th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>(±25mm)</td>
</tr>
<tr>
<td>Width or Diameter</td>
<td>(±10mm)</td>
</tr>
<tr>
<td>Variation from longitudinal axis (bow)</td>
<td>(1mm/m)</td>
</tr>
<tr>
<td>Variation from end squareness or skew</td>
<td>(±6mm/300mm,±13mm max.)</td>
</tr>
<tr>
<td>Position of Individual Strands</td>
<td>(±6mm)</td>
</tr>
<tr>
<td>Position of handling devices</td>
<td>(±150mm)</td>
</tr>
<tr>
<td>Longitudinal spacing of spiral reinforcement</td>
<td>(±19mm)</td>
</tr>
<tr>
<td>Local smoothness of any formed surface</td>
<td>(±3mm/1500mm)</td>
</tr>
</tbody>
</table>
Table 12.8: Maximum Dimensional Tolerances for Prestressed Concrete Stay-in-Place Forms

<table>
<thead>
<tr>
<th>Description</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (in direction of panel strands)</td>
<td>(+18mm, -6mm)</td>
</tr>
<tr>
<td>Width</td>
<td>(+6mm, -12mm)</td>
</tr>
<tr>
<td>Thickness</td>
<td>(+6mm, -3mm)</td>
</tr>
<tr>
<td>Variation from end squareness or skew</td>
<td>(+6mm)</td>
</tr>
<tr>
<td>Camber, sweep, and warping (1)</td>
<td>(±2mm per meter of length)</td>
</tr>
<tr>
<td>Position of individual strands:</td>
<td></td>
</tr>
<tr>
<td>Vertically</td>
<td>(+0mm, -6mm)</td>
</tr>
<tr>
<td>Horizontally</td>
<td>(±12mm)</td>
</tr>
<tr>
<td>Position of handling devices:</td>
<td></td>
</tr>
<tr>
<td>Parallel to length</td>
<td>(±75mm)</td>
</tr>
<tr>
<td>Transverse to length</td>
<td>(±50mm)</td>
</tr>
<tr>
<td>Local smoothness of any formed surface</td>
<td>(±3mm/1500mm)</td>
</tr>
</tbody>
</table>

Note(1): When measuring panel camber, account for dead load deflection of the panel. SIP form deck panels are designed to have no camber, only dead load deflection.

The Contractor shall remedy out-of-tolerance members in one of the following ways:
- Replacing the member at no additional cost to the Ministry.
- Correcting the member tolerance problem, if possible, using an approved correction procedure at no additional cost to the Ministry.
- If correction is not possible but the member is considered usable, The Contractor shall submit the member for review and acceptance at a reduced price under subsection “Conformity with plans and specification” in Part 1 of these specifications. A description of the problem and any proposed corrective action shall be included. Structural and physical evaluation by a Professional Engineer shall be provided, as required. If the submittal is rejected, the member shall be replaced at no additional cost to the Ministry.

12.6. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and this section requirements. For work acceptance, Contractor shall apply quality control for prestressing of concrete work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.

The Ministry shall apply quality assurance and verify the Contractor quality control procedures either through direct supervision or by carrying out neutrally quality assurance procedures using test on representative samples and in adequate numbers to judge about the quality level and accept or reject the executed works according to the principles detailed mentioned below in next paragraphs.

12.6.1. Quality Control

The work should be controlled and inspected to insure that all plans are correct and has all details of work, also drawing checking and review should be performed to assure that it is including all detailed information required according to the article 12.2.
and 12.3. Also, all materials used in concrete pre-stressing should be checked and ensure that fulfill the required specifications of article 12.4 and Table 12.11.

For work acceptance pre-stressing work should be controlled according to the pre-tensioning and post-tensioning methods used and the stages of applying the stress requirements according to the article 12.5.2 and 12.5.3.

12.6.2. Quality Assurance

Ministry, at any time, has the right to ensure the quality of pre-stressing work, by reviewing the test reports and manufacturing certificates coming with the importing materials, and are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that ensure the quality of pre-tensioning and post-tensioning used method according to the article 12.4 and Table 12.11.

12.7. Measurement and Payment

12.7.1. Measurement

The pre-stressing of cast-in-place concrete will be measured by the lump sum for each item or location listed in the contract documents.

12.7.2. Payment

No separate payment will be made for pre-stressing precast concrete members. Payment for pre-stressing precast concrete members shall be considered as included in the contract price paid for the precast members as provided for in Section 10, “Concrete Structures.”

The contract lump-sum price paid for pre-stressing cast-in-place concrete shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals; and for doing all work involved in furnishing, placing, and tensioning the pre-stressing steel in cast-in-place concrete structures, complete in place, as specified in the contract documents and in these Specifications, and as directed by the Engineer.

Full compensation for furnishing and placing additional concrete and deformed bar reinforcing steel required by the particular system used; ducts, anchoring devices, distribution plates, or assemblies and incidental parts; for furnishing samples for testing, working drawings, and for pressure grouting ducts shall be considered as included in the contract lump-sum price paid for pre-stressing cast-in-place concrete or in the contract price for furnishing precast members, and no additional compensation will be allowed therefore.

Payment will be made under one or more of the items in Table 12.9. And quality control requirements for pre-stressing are shown in Table 12.10.

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
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</thead>
<tbody>
<tr>
<td>12.1</td>
<td>Cast In Place Pre-stress Concrete</td>
<td>Cubic Meter</td>
</tr>
<tr>
<td>12.2</td>
<td>Precast Pre-stress Concrete</td>
<td>Each</td>
</tr>
</tbody>
</table>
Table 12.10: Quality Control Requirements For Pre-stressing

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensioning Requirements</td>
<td>Allowances for all losses</td>
<td>Assurance</td>
<td>In situ</td>
<td></td>
<td>Article 12.5.1</td>
</tr>
<tr>
<td></td>
<td>Specified in Article 5.9.5, “Loss of Prestress,” of the (MA-100-D-V1/2).</td>
<td>Assurance</td>
<td>In situ</td>
<td></td>
<td>Article 12.5.1</td>
</tr>
<tr>
<td></td>
<td>pre-tensioned members</td>
<td>Assurance</td>
<td>In situ</td>
<td></td>
<td>Article 12.5.1</td>
</tr>
<tr>
<td></td>
<td>The strand stress prior to seating shall not exceed ((0.8 f_s'))</td>
<td>Assurance</td>
<td>In situ</td>
<td></td>
<td>Article 12.5.1</td>
</tr>
<tr>
<td>Concrete Strength</td>
<td>Cast-in-place concrete shall not be post-tensioned until at least ten days</td>
<td>Number of days</td>
<td></td>
<td></td>
<td>Article 12.5.1.1</td>
</tr>
</tbody>
</table>

Table 12.11: AASHTO and ASTM designation and its title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>as specified</td>
<td>AASHTO M 275M/M 275</td>
<td>ASTM A 722/A 722M</td>
<td>Standard Specification for Uncoated High-Strength Steel Bars for Prestressing Concrete</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 204</td>
<td>ASTM A 421/A 421 M</td>
<td>Standard Specification for Uncoated Stress-Relieved Steel Wire for Prestressed Concrete</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 203M/M 203</td>
<td>ASTM A 416/A 416M</td>
<td>Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM C 1152/C 1152M</td>
<td></td>
<td>Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM C 33</td>
<td></td>
<td>Standard Specification for Concrete Aggregates</td>
</tr>
<tr>
<td>see table 12-2</td>
<td>ASTM C 1090</td>
<td></td>
<td>Standard Test Method for Measuring Changes in Height of Cylindrical Specimens of Hydraulic-Cement Grout</td>
</tr>
<tr>
<td>see table 12-2</td>
<td>ASTM C 940</td>
<td></td>
<td>Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory</td>
</tr>
<tr>
<td>see table 12-2</td>
<td>ASTM C 942</td>
<td></td>
<td>Standard Test Method for Compressive Strength of Grouts for Preplaced-Aggregate Concrete in the Laboratory</td>
</tr>
<tr>
<td>see table 12-2</td>
<td>ASTM C 953</td>
<td></td>
<td>Standard Test Method for Time of Setting of Grouts for Preplaced-Aggregate Concrete in the Laboratory</td>
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<td>ASTM DESIGNATION</td>
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<td>ASTM C 939</td>
<td>Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)</td>
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<td>ASTM C 940</td>
<td>Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory</td>
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<td>AASHTO T 277</td>
<td>ASTM C 1202</td>
<td>Standard Test Method for Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration</td>
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<td>ASTM D 4101</td>
<td>Standard Specification for Polypropylene Injection and Extrusion Materials</td>
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<td>ASTM D 3350</td>
<td>Standard Specification for Polyethylene Plastics Pipe and Fittings Materials</td>
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<td>a minimum Oxidation Induction Time (OIT) according to ASTM D 3895 of not less than 20 min</td>
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<td>ASTM D 3895</td>
<td>Standard Test Method for Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry</td>
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<td>as specified</td>
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<td>ASTM F 714</td>
<td>Standard Specification for Polyethylene Plastics Pipe and Fittings Materials</td>
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12.8. References


OKLAHOMA. “Oklahoma Department of Transportation Standard Specifications for Highway Construction” Sec. 503

AASHTO- "Bridges Construction Specifications" - 2004.

FHWA: "Standard Specifications For Construction of Roads and Bridges on Federal Highway Projects"- FP 03. Sec. 553.


MOT KSA:"General Specifications For Road And Bridge Construction"; November 1998.

SECTION 13. STEEL STRUCTURES

13.1. General

13.1.1. Description

This work shall consist of furnishing, fabricating, and erecting steel structures and structural steel portions of other structures in accordance with these Specifications, and in the contract documents.

Unless otherwise specified, the structural steel fabricating plant shall be certified under the AISC Quality Certification Program, Category I. The fabrication of fracture-critical members shall be Category III.

Details of design which are permitted to be selected by the Contractor shall conform to the (MA-100-D-V1/2 & V2/2).

Falsework used in the erection of structural steel shall conform to the provisions of Section 6, "Temporary Works".

Structural components designated in the contract documents as "fracture-critical" shall conform to the provisions of the AASHTO/ AWS D 1.5M/D 1.5 Bridge Welding Code, Section 12, "Fracture Control Plan (FCP) for Nonredundant Members."

Welding and weld qualification tests shall conform to the provisions of the current AASHTO/ A WS D 1.5M/D 1.5 Bridge Welding Code.

13.1.2. Notice of Beginning of Work

The Contractor shall give the Engineer ample notice of the beginning of work at the mill or in the shop so that inspection may be provided. No material shall be manufactured or work done in the shop before the Engineer has been so notified.

13.1.3. Inspection

Structural steel will be inspected at the fabrication site.

The Contractor shall furnish to the Engineer a copy of all mill orders and certified mill test reports. Mill test reports shall show the chemical analysis and physical test results for each heat of steel used in the work. With the approval of the Engineer, Certificates of Compliance shall be furnished in lieu of mill test reports for material that normally is not supplied with mill test reports and for items such as fills, minor gusset plates, and similar material when quantities are small and the material is taken from stock.

Certified mill test reports for steels with specified impact values shall include the results of Charpy V-Notch impact tests in addition to other test results. When fine grain practice is specified, the test report shall confirm the material that was so produced. Copies of mill orders shall be furnished at the time orders are placed with the Manufacturer. Certified mill test reports and Certificates of Compliance shall be furnished prior to the start of fabrication of material covered by these reports. The

1 The term “Mill” means any rolling mill or foundry where material for the work is to be manufactured.
Certificate of Compliance shall be signed by the Manufacturer and shall certify that the material is in conformance with the specifications to which it has been manufactured.

Material to be used shall be made available to the Engineer so that each piece can be examined. The Engineer shall have free access at all times to any portion of the fabrication site where the material is stored or where work on the material is being performed.

13.1.4. Shipping, Handling and Storing Materials

Members having a weight more than 26.5 kN shall have the mass marked thereon.

In handling and shipping of the steel work, every care shall be taken to avoid bending, scraping or overstressing the pieces. All pieces bent or otherwise damaged will be rejected.

The loading, transporting and unloading of structural material shall be conducted such that the metal will be kept clean. Material to be stored shall be placed above the ground on platforms, skids or other supports and shall be kept free from dirt, grease and other foreign material and properly drained and protected from corrosion. Girders and beams shall be placed upright and shored. Long members, such as columns and chords, shall be supported on skids placed near enough together to prevent damage from deflection.

13.1.5. Falsework

Falsework used for the erection of structural steel shall conform to the provisions in Section 6, "Temporary Structures" except that dead loads shall consist of the mass of the structural steel and any other portions of the structure which are supported by the falsework.

Falsework and forms supporting the concrete work on steel structures shall be constructed so that any loads applied to girder webs shall be applied within 150 mm of a flange or stiffener and shall be distributed in a manner that will not produce local distortion of the web. Temporary struts and ties shall be provided as necessary to resist lateral loads applied to the girder flanges and to prevent appreciable relative vertical movement between the edge of deck form and the adjacent steel girder.

Construction methods and equipment employed by the Contractor shall conform to the provisions in Article 3.3. Loads imposed on existing, new or partially completed structures shall not exceed the load carrying capacity of the structure, or portion of structure, as determined by the Load Factor Design methods of (MA-100-D-V1/2 & V2/2) using Load Group IB.

13.1.6. Continuous Members

If erection procedures are to be used which will provide the designed girder continuity for dead load, the Contractor shall furnish to the Engineer for review a statement of the intended steel erection procedures with calculations in sufficient detail to substantiate that the girder geometry will be correct.

If erection procedures are to be used which will provide the designed girder continuity for dead load, members with field joints shall be preassembled in a no-load condition in a horizontal or an upright position.

If erection procedures are to be used which will result in steel girders not attaining the continuity for dead load assumed in design, the Contractor shall furnish to the
Engineer for review a statement of steel erection procedures with calculations, in sufficient detail to substantiate that girder capacity and geometry will be correct.

If erection procedures are to be used which will result in steel girders not attaining the continuity for dead load assumed in design, the structure shall, after erection, have a load carrying capacity at least equal to the designed structure shown on the plans. The Contractor may increase the cross-sectional area or change the grades of steel to provide the specified load carrying capacity, subject to approval by the Engineer. Any additional steel or higher strength steels required to accommodate the method of erection selected shall be considered to be for the convenience of the Contractor and no additional payment will be made therefore.

13.2. Drawings

13.2.1. General

The Contractor shall submit to the Engineer for approval working drawings in the form of shop drawings, erection drawings and transportation drawings for structural steel. For initial review, six (6) sets of such drawings shall be submitted. After review, between six (6) and twelve (12) sets, as requested by the Engineer, shall be submitted for final approval and for use during construction.

The working drawings shall show any changes proposed in the work, details and calculations for connections not dimensioned on the plans, the direction of rolling of plates where specific orientation is required, the sequence of shop and field assembly and erection, welding sequences and procedures, the location of all butt welded splices on a layout drawing of the entire structure, the location of any temporary supports that are to be used, and the vertical alignment of the girder at each stage of the erection. Substantiating camber calculations and diagrams shall be submitted with the working drawings.

Working drawings shall be submitted sufficiently in advance of the start of the affected Work to allow time for review by the Engineer and correction by the Contractor of the drawings without delaying the Work. Such time shall be proportional to the complexity of the Work, but in no case shall such time be less than six (6) weeks.

Any material ordered by the Contractor and the fabrication of any material, prior to final approval of the drawings by the Engineer, shall be at the Contractor's risk.

13.2.2. Shop Drawings

The Contractor shall submit copies of the detailed shop drawings to the Engineer for approval. Shop drawings shall be submitted sufficiently in advance of the start of the affected work to allow time for review by the Engineer and corrections by the Contractor, if any, without delaying the work.

Shop drawings for steel structures shall give full, detailed dimensions and sizes of component parts of the structure and details of all miscellaneous parts, such as pins, nuts, bolts, drains, etc.

Where specific orientation of plates is required, the direction of rolling of plates shall be shown.

Unless otherwise specified in the contract documents, shop drawings shall identify each piece that is to be made of steel which is to be other than AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grade 250 steel.
13.2.3. Erection Drawings

The Contractor shall submit drawings fully illustrating the proposed method of erection. The drawings shall show details of all falsework bents, bracing, guys, dead-men, lifting devices, and attachments to the bridge members; sequence of erection, location of cranes and barges, crane capacities, location of lifting points on the bridge members, and weights of the members. The drawings shall be complete in detail for all anticipated phases and conditions during erection. Calculations may be required to demonstrate that factored resistances are not exceeded and that member capacities and final geometry will be correct.

13.2.4. Camber Diagram

A camber diagram shall be furnished to the Engineer by the Fabricator, showing the camber at each panel point in the cases of trusses or arch ribs, and at the location of field splices and fractions of span length (quarter points minimum) in the cases of continuous beam and girders or rigid frames. The camber diagram shall show calculated cambers to be used in preassembly of the structure in accordance with Article 13.5.3, “Preassembly of Field Connections.”

13.2.5. Transportation Drawings

If required, transportation drawings shall be furnished for approval. All support points, tie-downs, temporary stiffening trusses or beams, and any other details needed to support and brace the member shall be shown. The Contractor shall provide calculation sheets showing the dead load plus impact stresses induced by the loading and transportation procedure. The impact stresses to be used shall be of at least two hundred percent (200%) of the dead load stress. Total load to be used, including impact, shall not be less than three hundred percent (300%) of the dead load.

All members, both straight and curved, shall be shipped and stored in their upright position.

13.3. Materials

13.3.1. Structural Steel

13.3.1.1. General

Steel shall be furnished according to the following specifications. The grade or grades of steel to be furnished shall be as specified in the contract documents.

All steel for use in main load-carrying member components subject to tensile stress shall conform to the applicable Charpy V-Notch impact test requirements of AASHTO M 270M/M 270 (ASTM A 709/A 709M).

Welded girders made of ASTM A 709/A 709M, Grade HPS 485W, steels shall be fabricated in accordance with the AASHTO Guide Specifications for Highway Bridge Fabrication with HPS70W Steel, which supplements the AASHTO/ A WS D 1.5M/D 1.5 Bridge Welding Code.

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1 Guy: a rope, cable, or appliance used to guide and steady an object being hoisted or lowered, or to secure anything likely to shift its position.
2 Dead-man: a log, concrete block, etc., buried in the ground as an anchor.
13.3.1.2. Carbon Steel

Unless otherwise specified in the contract documents, structural carbon steel for bolted or welded construction shall conform to: Structural Steel for Bridges, AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grade 250.

13.3.1.3. High-Strength, Low-Alloy Structural Steel

High-strength, low-alloy steel shall conform to Structural Steel for Bridges, AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grades 345, 345S, 345W, or HPS 345W.

13.3.1.4. High-Strength, Low-Alloy, Quenched, and Tempered Structural Steel Plate

High-strength, low-alloy, quenched, and tempered steel plate shall conform to Structural Steel for Bridges, AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grades 485W or HPS 485W.

13.3.1.5. High-Yield-Strength, Quenched, and Tempered Alloy-Steel Plate

High-yield-strength, quenched, and tempered alloy steel plate shall conform to:

- Structural Steel for Bridges AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grades 690 or 690W.
- Quenched-and-tempered alloy-steel structural shapes and seamless mechanical tubing meeting all of the mechanical and chemical requirements of AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grades 690 or 690W steel, except that the specified maximum tensile strength may be 965 MPa for structural shapes and 1000 MPa for seamless mechanical tubing, shall be considered as AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grades 690 and 690W steel.

13.3.1.6. Eye bars

Steel for eye bars shall be of a weld able grade. These grades include structural steel conforming to:

- Structural Steel for Bridges, AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grade 250.
- Structural Steel for Bridges, AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grades 345, 345W, or HPS 345W.

13.3.1.7. Structural Tubing

Structural tubing shall be either cold-formed welded or seamless tubing conforming to ASTM A 500, Grade B, or hot-formed welded or seamless tubing conforming to ASTM A 501.

13.3.2. High-Strength Fasteners

13.3.2.1. General

High-strength bolts for structural steel joints shall conform to either AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) or AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)). When high-strength bolts are used with unpainted weathering grades of steel, the bolts shall be Type 3.
The supplier shall provide a lot of number appearing on the shipping package and a certification noting when and where all testing was done, including rotational capacity tests, and zinc thickness when galvanized bolts and nuts are used.

The maximum hardness for AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) bolts shall be 33 HRC.

Proof-load tests (ASTM F 606 (ASTM F 606M), Method I) shall be required for the bolts. Wedge tests of full-size bolts are required in accordance with Section 8.3 of AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)). Galvanized bolts shall be wedge tested after galvanizing. Proof-load tests of AASHTO M 291 (ASTM A 563) (AASHTO M 291 M (ASTM A 563M)) are required for the nuts. The proof-load tests for nuts to be used with galvanized bolts shall be performed after galvanizing, over tapping, and lubricating.

Except as noted below:
- Nuts for AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) bolts shall conform to AASHTO M 291 (ASTM A 563) (AASHTO M 291M (ASTM A 563M)), Grades DH, DH3, C, C3, and D (Property Class 8S, 8S3, 10S, or 10S3).
- Nuts for AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) bolts shall conform to the requirements of AASHTO M 291 (ASTM A 563) (AASHTO M 291M (ASTM A 563M)), Grades DH and DH3 (Property Class 10S or 10S3).

The exceptions are:
- Nuts to be galvanized (hot-dip or mechanically galvanized) shall be Grade DH (Property Class 10S).
- Nuts to be used with AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) Type 3 bolts shall be Grade C3 or DH3 (Property Class 8S3 or 10S3).
- Nuts to be used with AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)), Type 3 bolts shall be Grade DH3 (Property Class 10S3).

All galvanized nuts shall be lubricated with a lubricant containing a visible dye. Black bolts must be oily to touch when delivered and installed.

Washers shall be hardened steel washers conforming to the requirements of AASHTO M 293 (ASTM F 436) (AASHTO M 293M (ASTM F 436M)) and "Requirements for Washers".

13.3.2.2. Identifying Marks

AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) for bolts and the specifications referenced herein for nuts require that bolts and nuts manufactured to the specification be identified by specific markings atop the bolt head and on one face of the nut. Head markings must identify the grade by the symbol "A 325" ("A 325M"), the Manufacturer, and the type, if Type 3. Nut markings must identify the property class, the Manufacturer, and, if Type 3, the type. Markings on direct tension indicators (DTI, ASTM F 959 (ASTM F 959M)) must identify the Manufacturer and Type "325" (Class "8.8"). Other washer markings must identify the Manufacturer, and, if Type 3, the type.

AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) for bolts and the specifications referenced therein for nuts require that bolts and nuts manufactured to the specifications be identified by specific markings on the top of the
Section 13: Steel Structures

13.3.2.3. Dimensions

Bolt and nut dimensions shall conform to the requirements for heavy hexagon structural bolts and heavy semi-finished hexagon nuts (metric heavy hexagon structural bolts and metric heavy semi-finished hexagon nuts) given in ANSI Standards B 18.2.1 and B 18.2.2 (B 18.2.3.7M and B 18.2.4.6M), respectively.

13.3.2.4. Galvanized High-Strength Fasteners

AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) bolts shall not be galvanized.

When fasteners are galvanized, they shall be specified to be hot-dip galvanized in accordance with AASHTO M 232M/M 232 (ASTM A 153/ A 153M), Class C or mechanically galvanized in accordance with AASHTO M 298 (ASTM B 695), Class 50 (Class 345). Bolts to be galvanized shall be either AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) Type I. Galvanized bolts shall be tension tested after galvanizing. Washers, nuts, and bolts of any assembly shall be galvanized by the same process. The nuts should be over tapped to the minimum amount required for the fastener assembly and shall be lubricated with a lubricant containing a visible dye so a visual check can be made for the lubricant at the time of field installation.

13.3.2.5. Alternative Fasteners

Other fasteners or fastener assemblies, such as those:
- conforming to the requirements of ASTM F 1852;
- meeting the materials, manufacturing, and chemical composition requirements of AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) or AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M));
- meeting the mechanical property requirements of the same specification in full-size tests;
- having body diameter and bearing areas under the head and nut, or their equivalent, not less than those provided by a bolt and nut of the same nominal dimensions prescribed in Article 13.3.2.3, may be used.

These fasteners are subject to the approval of the Engineer. Such alternate fasteners may differ in other dimensions from those of the specified bolts and nuts.

Subject to the approval of the Engineer, high-strength steel lock-pin and collar fasteners may be used as an alternative for high-strength bolts as shown in the contract documents. The shank and head of high-strength steel lock-pin and collar fasteners shall meet the requirements of Article 13.3.2.3. Each fastener shall provide a solid-shank body of sufficient diameter to provide tensile and shear strength equivalent to or greater than that of the bolt specified in the contract documents and shall have a cold forged head on one end, of type and dimensions as approved by the Engineer; a shank length suitable for material thickness fastened; locking grooves; breakneck groove; and pull grooves (all annular grooves) on the opposite end. Each fastener shall provide a steel locking collar of proper size for shank diameter used which, by means of suitable
installation tools, is cold-swaged into the locking grooves forming head for the grooved end of the fastener after the pull groove section has been removed. The steel locking collar shall be a standard product of an established Manufacturer of lock-pin and collar fasteners, as approved by the Engineer.

13.3.2.6. Load-Indicator Devices

Load-indicating devices may be used in conjunction with bolts, nuts and washers specified in Article [13.3.2.1]. Load-indicating devices shall conform to the requirements of ASTM Specification for Compressible-Washer Type Direct Tension Indicators for Use with Structural Fasteners, ASTM F 959 (ASTM F 959M), except as provided in the following paragraph.

Subject to the approval of the Engineer, alternative design direct tension indicating devices may be used provided they satisfy the requirements of Article [13.5.6.4.6] or other requirements detailed in specifications provided by the Manufacturer and subject to the approval of the Engineer.

13.3.3. Welded Stud Shear Connectors

13.3.3.1. General

Stud shear connectors shall conform to the requirements of Cold-Finished Carbon Steel Bars and Shafting, AASHTO M 169 (ASTM A 108), cold-drawn bars, Grades 1015, 1018, or 1020, either semi- or fully-killed. If flux retaining caps are used, the steel for the caps shall be of a low-carbon grade suitable for welding and shall comply with Cold-Rolled Carbon Steel Strip, ASTM A 109/A 109M.

Tensile properties, as determined by tests of bar stock after drawing or of finished studs, shall conform to the requirements in Table 13.1 in which the yield strength is as determined by a two-tenth percent (0.2%) offset method.

<table>
<thead>
<tr>
<th>Table 13.1: Tensile Properties of Stud Shear Connectors.</th>
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<tbody>
<tr>
<td>Tensile Strength</td>
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<tr>
<td>Yield Strength</td>
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<tr>
<td>Elongation</td>
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<tr>
<td>Reduction of Area</td>
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</table>

13.3.3.2. Test Methods

Tensile properties shall be determined in accordance with the applicable sections of AASHTO T 244 (ASTM A 370), Mechanical Testing of Steel Products. Tensile tests of finished studs shall be made on studs welded to test plates using a test fixture similar to that shown in Figure 7.2 of the current AASHTO/AWS D1.5M/D1.5 Bridge Welding Code. If fracture occurs outside of the middle half of the gage length, the test shall be repeated.

13.3.3.3. Finish

Finished studs shall be of uniform quality and condition, free from irregularities such as laps, fins, seams, cracks, twists, bends, or other injurious defects. Finish shall be as produced by cold-drawing, cold-rolling, or machining.
13.3.3.4. Certification

The Manufacturer shall certify that the studs as delivered are in accordance with the material requirements of this section. Certified copies of in-plant quality-control test reports shall be furnished to the Engineer upon request.

13.3.3.5. Check Samples

The Engineer may select, at the Contractor's expense, studs of each type and size used under the contract documents as necessary for checking the requirements of this Section.

13.3.4. Steel Forgings and Steel Shafting

13.3.4.1. Steel Forgings

Steel forgings shall conform to the Specifications for Steel Forgings Carbon and Alloy for General Use, AASHTO M 102/M 102 (ASTM A 668/A 668M), Classes C, D, F, or G.

13.3.4.2. Cold-Finished Carbon Steel Shafting

Cold-finished carbon steel shafting shall conform to the specifications for Cold-Finished Carbon Steel Bars Standard Quality, AASHTO M 169 (ASTM A 108). Grades 10160 through 10300, inclusive, shall be furnished unless otherwise specified in the contract documents.

13.3.5. Steel Castings

13.3.5.1. Mild Steel Castings

Steel castings for use in highway bridge components shall conform to Standard Specifications for Steel Castings for Highway Bridges, ASTM A 781/A 781 M, Class 70 (Class 485), or Standard Specifications for Steel Castings, Carbon, for General Application, AASHTO M 103/M 103 (ASTM A 27/A27M), Class 70 or Class 485 or Grade 485-250, unless otherwise specified in contract documents.

13.3.5.2. Chromium Alloy-Steel Castings


13.3.6. Iron Castings

13.3.6.1. Materials

Gray iron castings shall conform to the Specification for Gray Iron Castings, AASHTO M105 or ASTM A 481/A 48M, Class 30, unless otherwise specified in the contract documents.

Ductile iron castings shall conform to the Specifications for Ductile Iron Castings, ASTM A 536, Grade 414-276-18, unless otherwise specified in the contract documents. Test specimens from parts integral with the castings, such as risers, shall be tested for castings with a weight more than 44 kN to determine that the required quality is obtained in the castings in the finished condition.
Malleable castings shall conform to the Specification for Ferritic Malleable Iron Castings, ASTM A 47/A 47M. Grade 241441 shall be furnished unless otherwise specified in the contract documents.

13.3.6.2. Work Quality and Finish
Iron castings shall be true to pattern in form and dimensions, free from pouring faults, sponginess, cracks, blow holes, and other defects in positions affecting their strength and function for the service intended.

Castings shall be boldly filleted at angles and the arises shall be sharp and perfect.

13.3.6.3. Cleaning
All castings must be sandblasted or otherwise effectively cleaned of scale and sand so as to present a smooth, clean, and uniform surface.

13.3.7. Galvanizing
When galvanizing is specified in the contract documents, ferrous metal products, other than fasteners and hardware items, shall be galvanized in accordance with the Specifications for Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shape Plates, Bars, and Strip, AASHTO M 111M/M 111 (ASTM A 123/A 123M). Fasteners and hardware items shall be galvanized in accordance with the Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware, AASHTO M 232M/M 232 (ASTM A 153/A 153M), except as noted in Article 13.3.2.4, "Galvanized High-Strength Fasteners".

13.3.8. Storage of Materials
Structural material, either plain or fabricated, shall be stored above the ground on platforms, skids, or other supports. It shall be kept free from dirt, grease, and other foreign matter, and shall be protected as far as practicable from corrosion. Storage of high-strength fasteners shall conform to Article 13.5.6.4, "Installation".

13.4. Fabrication

13.4.1. General
The provisions in this Section shall follow the requirements for fabrication in ANSI/AASHTO/AWS D1.5.

13.4.2. Quality of Workmanship
Workmanship and finish shall be equal to the best general practices in modern bridge fabricating facilities.

13.4.3. Identification of Steels during Fabrication
The Contractor's system of assembly, which includes marking individual pieces, and the issuance of cutting instructions to the shop shall be such as to maintain identity of the original piece.

The Contractor may furnish material that can be identified by heat number and mill test report from stock.

During fabrication, up to the point of assembling members, each piece of steel, other than Grade 250 steel, shall show clearly and legibly its specification.
Any piece of steel, other than Grade 250 steel, which will be subject to fabricating operations such as blast cleaning, galvanizing, heating for forming, or painting which might obliterate marking prior to assembling into members, shall be marked for grade by steel die stamping or by a substantial tag firmly attached. Steel die stamps shall be low stress-type.

Upon request by the Engineer, the Contractor shall furnish an affidavit certifying that throughout the fabrication operation the identification of steel has been maintained in accordance with this specification.

13.4.4. Plates

13.4.4.1. Direction of Rolling

Unless otherwise specified in the contract documents, steel plates for main members and splice plates for flanges and main tension members, not secondary members, shall be cut and fabricated so that the primary direction of rolling is parallel to the direction of the main tensile and/or compressive stresses.

13.4.4.2. Plate-Cut Edges

1. Edge Planning

Sheared edges of plate more than 16 mm in thickness and carrying calculated stress shall be planed, milled, ground, or thermal-cut to a depth of 6 mm.

2. Oxygen Cutting

Oxygen cutting of structural steel shall conform to the requirements of the current AASHTO/AWS D1.5M/D1.5 Bridge Welding Code.

3. Visual Inspection and Repair of Plate-Cut Edges

Visual inspection and repair of plate-cut edges shall be in accordance with the current AASHTO/ AWS D 1.5M/D 1.5 Bridge Welding Code.

13.4.4.3. Bent Plates

1. General

Cold-bending of fracture-critical steel members and attachments is prohibited. Perform cold-bending of other steels or members, in accordance with the AASHTO/AWS 01.5M/D 1.5 Bridge Welding Code and Table 13.2 and in a manner such that no cracking occurs.

2. Cold-Bending

Unless otherwise approved, the minimum bend radii for cold-forming (at room temperature), measured to the concave face of the plate, are given in Table 13.2. If a smaller radius is required, heat may need to be applied as a part of the bending procedure. Provide the heating procedure for review by the Engineer. For grades not included in Table 13.2, follow minimum bend radii recommendations of the plate Producer.

If possible, orient bend lines perpendicular to the direction of final rolling of the plate. If the bend line is parallel to the direction of final rolling, multiply the suggested minimum radii in Table 13.2 by 1.5.
3. Hot-Bending

If a radius shorter than the minimum specified for cold-bending is essential, the plates shall be bent hot at a temperature not greater than six hundred and fifty degree Celsius (650°C), except for AASHTO M 270M/M 270 (ASTM A 709/ A 709M), Grades 485W, 690, and 690W.

If Grades 690 and 690W steel plates or Grade 485W plates require bending, a temperature greater than five hundred and ninety-five degree Celsius (595°C) shall be applied; upon heating and bending, the steel shall be quenched and tempered in accordance with the producing mill's practice and tested to verify restoration of specified properties, as directed by the Engineer.

However, Grade HPS 485W steel, which requires bending, shall not be heated to a temperature greater than five hundred and ninety-five degree Celsius (595°C). Requenching and tempering is not required for Grade HPS 485W steel heated to this limit.

13.4.5. Fit of Stiffeners

End bearing stiffeners for girders and stiffeners intended as supports for concentrated loads shall have full bearing (either milled, ground, or on weldable steel in compression areas of flanges, welded as specified in the contract documents) on the flanges to which they transmit load or from which they receive load. Intermediate stiffeners not intended to support concentrated loads, unless specified in the contract documents, shall have a tight fit against the compression flange.

13.4.6. Abutting Joints

Abutting ends in compression members of trusses and columns shall be milled or saw-cut to give a square joint and uniform bearing. At other joints, not required to be faced, the opening shall not exceed 10 mm.

13.4.7. Facing of Bearing Surfaces

The surface finish of bearing, base plates, and other bearing surfaces that are to come in contact with each other or with concrete shall meet the ANSI surface roughness requirements as defined in ANSI B46.1, Surface Roughness, Waviness, and Lay, Part I:

---

Table 13.2: Minimum Cold-Bending Radii.

<table>
<thead>
<tr>
<th>Thickness, in (t)</th>
<th>Up to 0.75</th>
<th>Over 0.75 to 1.0, incl.</th>
<th>Over 1.0 to 2.0, incl.</th>
<th>Over 2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>AASHTO M 270M/M270 (ASTM A 709/ A 709M) Grades, MPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>1.5t</td>
<td>1.5t</td>
<td>1.5t</td>
<td>2.0t</td>
</tr>
<tr>
<td>345, 345S, 345W, or HPS 345W</td>
<td>1.5t</td>
<td>1.5t</td>
<td>2.0t</td>
<td>2.5t</td>
</tr>
<tr>
<td>HPS 485W</td>
<td>1.5t</td>
<td>1.5t</td>
<td>2.5t</td>
<td>3.0t</td>
</tr>
<tr>
<td>690</td>
<td>1.75t</td>
<td>2.25t</td>
<td>4.5t</td>
<td>5.5t</td>
</tr>
<tr>
<td>690W</td>
<td>1.75t</td>
<td>2.25t</td>
<td>4.5t</td>
<td>5.5t</td>
</tr>
</tbody>
</table>
13.4.8. Straightening Material

The straightening of plates, angles, other shapes, and built-up members, when permitted by the Engineer, shall be done by methods that will not produce fracture or other damage to the metal. Distorted members shall be straightened by mechanical means or, if approved by the Engineer, by carefully planned procedures and supervised application of a limited amount of localized heat, except that heat-straightening of AASHTO M 270M/M 270 (ASTM A 709/A 709M) Grades 485W, HPS 485W, 690, and 690W steel members shall be done only under rigidly controlled procedures, each application subject to the approval of the Engineer. In no case shall the maximum temperature exceed values in Table 13.3.

### Table 13.3: Maximum Straightening Temperature

<table>
<thead>
<tr>
<th>AASHTO M 270M/M 270 (ASTM A 709/ A 709M) Grades</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>485W</td>
<td>566°C</td>
</tr>
<tr>
<td>HPS 485W</td>
<td>593°C</td>
</tr>
<tr>
<td>690</td>
<td>593°C</td>
</tr>
<tr>
<td>690W</td>
<td>593°C</td>
</tr>
</tbody>
</table>

In all other steels, the temperature of the heated area shall not exceed six hundred and fifty degree Celsius (650°C) as controlled by temperature indicating crayons, liquids, or bimetal thermometers. Heating in excess of the limits shown shall lead to the rejection of the affected steel member, unless the Engineer allows testing to verify material integrity.

Parts to be heat-straightened shall be substantially free of stress and from external forces, except stresses resulting from mechanical means used in conjunction with the application of heat.

Evidence of fracture following straightening of a bend or buckle shall be a cause for rejection of the damaged piece.
13.4.9. Annealing and Stress Relieving

Structural members that are indicated in the contract documents to be annealed or normalized shall have finished machining, boring, and straightening done subsequent to heat treatment. Normalizing and annealing (full annealing) shall be as specified in ASTM A 941. The temperatures shall be maintained uniformly throughout the furnace during the heating and cooling so that the temperature at no two points on the member will differ by more than fifty degree Celsius (55°C) at any one time.

Members of AASHTO M 270M/M 270 (ASTM A 709/ A 709M) Grades 690/690W or Grade 485W steels shall not be annealed or normalized and shall be stress relieved only with the approval of the Engineer.

A record of each furnace charge shall identify the pieces in the charge and show the temperatures and the actually used schedule. Proper instruments, including recording pyrometers, shall be provided for determining at any time the temperatures of members in the furnace. The records of the treatment operation shall be available to and meet the approval of the Engineer. The holding temperature for stress relieving shall be in accordance with Section 4.4 of the current AASHTO/A WS D1.5M/D1.5 Bridge Welding Code.

Members, such as bridge shoes, pedestals, or other parts that are built up by welding sections of plate together shall be stress relieved in accordance with the procedure of Section 4.4 of the current AASHTO/ A WS D 1.5M/D 1.5 Bridge Welding Code, when required by the contract documents.

13.4.10. Bolt Holes

13.4.10.1. Holes for High-Strength Bolts and Unfinished Bolts

1. General

All holes for bolts shall be either punched or drilled, except as noted herein. The width of each standard bolt hole shall be taken as the nominal diameter of the bolt plus 2 mm. The standard hole size for metric bolts M24 and under shall be taken as the bolt diameter plus 2 mm. For metric bolts M27 and over, the standard hole size shall be taken as the bolt diameter plus 3 mm. Material forming parts of a member composed of not more than five thicknesses of metal may be punched full-size whenever the thickness of the material is not greater than 20 mm for structural steel, 16 mm for high-strength steel, or 12 mm for quenched-and-tempered alloy steel, unless subpunching and reaming are required under Article [13.4.10.2.5].

When material is thicker than 20 mm for structural steel, 16 mm for high-strength steel, or 12 mm for quenched-and-tempered alloy steel, all holes shall either be sub drilled and reamed or drilled full-size. Also, when more than five thicknesses are joined or, as required by Article [13.4.10.2.5], material shall be sub drilled and reamed or drilled full-size while in assembly.

When required, all holes shall be either subpunched or subdrilled (subdrilled if thickness limitation governs) 5 mm smaller and, after assembling, reamed or drilled to full size.

When shown in the contract documents, enlarged or slotted holes are allowed with high-strength bolts.
2. Punched Holes

The diameter of the die shall not exceed the diameter of the punch by more than 1.5 mm. If any holes must be enlarged to admit the bolts, such holes shall be reamed. Holes must be clean-cut without torn or ragged edges. The slightly conical hole that naturally results from punching operations shall be considered acceptable.

3. Reamed or Drilled Holes

Reamed or drilled holes shall be cylindrical, perpendicular to the member, and shall comply with the requirements of Article 3.4.10.1.1 as to size. Where practical, reamers shall be directed by mechanical means. Burrs on the outside surfaces shall be removed. Reaming and drilling shall be done with twist drills, twist reamers, or rotobroach cutters. Connecting parts requiring reamed or drilled holes shall be assembled and securely held while being reamed or drilled and shall be match-marked before disassembling.

4. Accuracy of Holes

Holes not more than 0.8 mm larger in diameter than the true decimal equivalent of the nominal diameter that may result from a drill or reamer of the nominal diameter shall be considered acceptable. The width of slotted holes which are produced by flame cutting or a combination of drilling or punching and flame cutting should be not more than 0.8 mm greater than the nominal width. The flame-cut surface shall be ground smooth.

13.4.10.2. Accuracy of Hole Group

1. Before Reaming

All holes punched full-size, subpunched, or subdrilled shall be so accurately punched that after assembling (before any reaming is done) a cylindrical pin 3 mm smaller in diameter than the nominal size of the punched hole may be entered perpendicular to the face of the member, without drifting, in at least seventy-five percent (75%) of the contiguous holes in the same plane. If the requirement is not fulfilled, the badly punched pieces shall be rejected. If any hole will not pass a pin 5 mm smaller in diameter than the nominal size of the punched hole, this shall be a cause for rejection.

2. After Reaming

When holes are reamed or drilled, eighty-five percent (85%) of the holes in any contiguous group shall, after reaming or drilling, show no offset greater than 0.8 mm between adjacent thicknesses of metal.

All steel templates shall have hardened steel bushings in holes accurately dimensioned from the centerlines of the connection as inscribed on the template. The centerlines shall be used in locating accurately the template from the milled or scribed ends of the members.

3. Numerically-Controlled Drilled Field Connections

In lieu of subsized holes and reaming while assembled, or drilling holes full-size while assembled, the Contractor shall have the option to drill or punch bolt holes full-size in unassembled pieces and/or connections including templates for use with matching subsized and reamed holes, by means of suitable numerically-controlled
(N/C) drilling or punching equipment. Full-size punched holes shall meet the requirements of Article [13.4.10.1].

If N/C drilling or punching equipment is used, the Contractor shall be required to demonstrate the accuracy of this drilling or punching procedure in accordance with the provisions of Article [13.5.3.3], "Check Assembly Numerically-Controlled Drilling," by means of checking assemblies.

Holes drilled or punched by N/C equipment shall be drilled or punched to appropriate size either through individual pieces or drilled through any combination of pieces held tightly together.

4. Holes for Ribbed Bolts, Turned Bolts, or Other Approved Bearing-Type Bolts

All holes for ribbed bolts, turned bolts, or other approved bearing-type bolts shall be subpunched or subdrilled 5 mm smaller than the nominal diameter of the bolt and reamed when assembled, or drilled to a steel template or, after assembling, drilled from the solid at the option of the Fabricator. In any case, the finished holes shall provide a driving fit as specified in the contract documents.

5. Preparation of Field Connections

Holes in all field connections and field splices of main member of trusses, arches, continuous-beam spans, bents, towers (each face), plate girders, and rigid frames shall be subpunched or subdrilled and subsequently reamed while assembled or drilled full-size through a steel template while assembled. Holes for field splices of rolled beam stringers continuous over floor beams or cross frames may be drilled full-size unassembled to a steel template. All holes for floor beams or cross frames may be drilled full-size unassembled to a steel template, except that all holes for floor beam and stringer field end connections shall be subpunched and reamed while assembled or drilled full-size to a steel template. Reaming or drilling full-size of field-connection holes through a steel template shall be done after the template has been located with utmost care as to position and angle and firmly bolted in place. Templates used for reaming matching members or the opposite faces of a single member shall be exact duplicates. Templates used for connections on like parts or members shall be so accurately located that the parts or members are duplicates and require no match-marking.

For any connection, in lieu of subpunching and reaming or subdrilling and reaming, the Fabricator may, at the Fabricator’s option, drill holes full-size with all thicknesses or material assembled in proper position.

13.4.11. Pins and Rollers

13.4.11.1. General

Pins and rollers shall be accurately turned to the dimensions shown on the drawings and shall be straight, smooth, and free from flaws. Pins and rollers more than 225 mm in diameter shall be forged and annealed. Pins and rollers 225 mm or less in diameter may be either forged and annealed or cold-finished carbon-steel shafting.

In pins larger than 225 mm in diameter, a hole not less than 50 mm in diameter shall be bored full-length along the axis after the forging has been allowed to cool to a temperature below the critical range, under suitable conditions to prevent damage by rapid cooling, and before being annealed.
13.4.11.2. Boring Pin Holes

Pin holes shall be bored true to the specified diameter, smooth and straight, at right angles with the axis of the member and parallel with each other unless otherwise required. The final surface shall be produced by a finishing cut.

The diameter of the pin hole shall not exceed that of the pin by more than 0.5 mm for pins 125 mm or less in diameter, or by 0.8 mm for larger pins.

The distance outside to outside of end holes in tension members and inside to inside of end holes in compression members shall not vary from that specified more than 0.8 mm. Boring of pin holes in built-up members shall be done after the member has been assembled.

13.4.11.3. Threads for Bolts and Pins

Threads for all bolts and pins for structural steel construction shall conform to the United Standard Series UNC ANSI B 1.1, Class 2A for external threads and Class 2B for internal threads, except that pin ends having a diameter of 35 mm or more shall be threaded six threads to the inch (metric screw threads-M Profile ANSI B 1.13M with a tolerance Class 6g for external threads and 6H for internal threads).

13.4.12. Eyebars

Pin holes may be flame-cut at least 50 mm smaller in diameter than the finished pin diameter. All eyebars that are to be placed side by side in the structure shall be securely fastened together in the order that they will be placed on and bored at both ends while so clamped. Eyebars shall be packed and match-marked for shipment and erection. All identifying marks shall be stamped with steel stencils on the edge of one head of each member after fabrication is completed so as to be visible when the bars are nested in place on the structure. Steel die stamps shall be low stress-type. No welding is allowed on eyebars or to secure adjacent eyebars.

The eyebars shall be straight and free from twists and the pin holes shall be accurately located on the centerline of the bar. The inclination of any bar to the plane of the truss shall not exceed a slope of five-tenth percent (0.5%). The edges of eyebars that lie between the transverse centerline of their pin holes shall be cut simultaneously with two mechanically operated torches abreast of each other, guided by a substantial template, in such a manner as to prevent distortion of the plates.

13.4.13. Curved Girders

13.4.13.1. General

Flanges of curved, welded girders may be cut to the radii specified in the contract documents or curved by applying heat as specified in the succeeding articles providing the radii is not less than allowed by Article 10.15.2, "Minimum Radius of Curvature," of the AASHTO Standard Specifications for Highway Bridges, 17th Edition, Design Specifications.

13.4.13.2. Heat-Curving Rolled Beams and Welded Girders

1. Materials

Except for ASTM A 709/A 709M Grade HPS 485W steel, steels that are manufactured to a specified minimum yield point greater than 345 MPa shall not be heat-curved.
2. Camber

Girders shall be cambered before heat-curving. Camber for rolled beams may be obtained by heat-cambering methods approved by the Engineer. For plate girders, the web shall be cut to the prescribed camber with suitable allowance for shrinkage due to cutting, welding, and heat-curving. However, subject to the approval of the Engineer, moderate deviations from specified camber may be corrected by a carefully supervised application of heat.

3. Measurement of Curvature and Camber

Horizontal curvature and vertical camber shall be measured for final acceptance after all welding and heating operations are completed and the flanges have cooled to a uniform temperature. Horizontal curvature shall be checked with the girder in the vertical position.

13.4.14. Orthotropic-Deck Superstructures

1. General

Dimensional tolerance limits for orthotropic-deck bridge members shall be applied to each completed but unloaded member and shall be as specified in paragraph 3.5 of the current AASHTO/ A WS D 1.5M/D 1.5 Bridge Welding Code, except as follows:

- The superstructure sections of the bridge in the form of metal slabs perpendicular Orthotropic - Deck
- The deviation from detailed flatness, straightness, or curvature at any point shall be the perpendicular distance from that point to a template edge which has the detailed straightness or curvature and which is in contact with the element at two other points.
- The template edge may have any length not exceeding the greatest dimension of the element being examined and, for any panel, not exceeding 1.5 times the least dimension of the panel; it may be placed anywhere within the boundaries of the element.
- The deviation shall be measured between adjacent points of contact of the template edge with the element; the distance between these adjacent points of contact shall be used in the formulas to establish the tolerance limits for the segment being measured whenever this distance is less than the applicable dimension of the element specified for the formula.

13.4.14.2. Flatness of Panels

The maximum deviation, \( \delta \), from detailed flatness or curvature of a panel shall not exceed the greater of 5 mm or:

\[
\delta \leq \frac{D}{726\sqrt{T}}
\]

Where:

\( \delta \) = maximum deviation in mm.
\( D \) = the least dimension along the boundary of the panel in mm.
\( T \) = the minimum thickness of the plate comprising the panel in mm.
13.4.14.3. Straightness of Longitudinal Stiffeners Subject To Calculated Compressive Stress, Including Orthotropic-Deck Rib

The maximum deviation, $\delta$, from detailed straightness or curvature in any direction perpendicular to its length of a longitudinal web stiffener or other stiffener subject to calculated compressive stress shall not exceed:

$$\delta \leq \frac{L}{480}$$

Where:
$L = \text{the length of the stiffener or rib between cross members, webs, or flanges, mm}$

13.4.14.4. Straightness of Transverse Web Stiffeners and Other Stiffeners Not Subject to Calculated Compressive Stress

The maximum deviation, $\delta$, from detailed straightness or curvature in any direction perpendicular to its length of a transverse web stiffener or other stiffener not subject to calculated compressive stress shall not exceed:

$$\delta \leq \frac{L}{240}$$

13.4.15. Full-Size Tests

When full-size tests of fabricated structural members or eyebars are required in the contract documents, the Contractor shall provide suitable facilities, material, supervision, and labor necessary for making and recording the required tests. The contractor shall provide the Engineer with detailed testing plan that includes: the loading pattern and the testing setup, the number of cycles per loading, the frequency of the loading, and the layout of the instrumentation gauges.

The members tested in accordance with the contract documents shall be paid for in accordance with Article 13.9.2, "Basis of Payment".

13.4.16. Marking and Shipping

Each member shall be painted or marked with an erection mark for identification and an erection diagram showing these marks shall be furnished to the Engineer.

The Contractor shall furnish to the Engineer as many copies of material orders, shipping statements, and erection diagrams as the Engineer may direct. The mass of the individual members shall be shown on the statements. Members having a weight of more than 26.5 kN shall have the mass marked thereon. Structural members shall be loaded on trucks or cars in such a manner that they may be transported and unloaded at their destination without being damaged.

Bolts, nuts, and washers (where required) from each rotational-capacity lot shall be shipped in the same container. If there is only one production lot number for each size of nut and washer, the nuts and washers may be shipped in separate containers. Pins, small parts, and packages of bolts, washers, and nuts shall be shipped in boxes, crates, kegs, or barrels but the gross weight of any package shall not exceed 1.3 kN. A list and description of the contained materials shall be plainly marked on the outside of each shipping container.
13.5. Assembly

13.5.1. Bolting

Surfaces of metal in contact shall be cleaned before assembling. The parts of a member shall be assembled, well pinned, and firmly drawn together before drilling, reaming, or bolting is commenced. Assembled pieces shall be taken apart, if necessary, for the removal of burrs and shavings produced by the operation. The member shall be free from twists, bends, and other deformation.

The drifting done during assembly shall be only such as to bring the parts into position and not sufficient to enlarge the holes or distort the metal.

13.5.2. Welded Connections

Surfaces and edges to be welded shall be smooth, uniform, clean, and free of defects which would adversely affect the quality of the weld. Edge preparation shall be done in accordance with the current AASHTO/AWS D1.5M/D 1.5 Bridge Welding Code.

13.5.3. Preassembly of Field Connections

13.5.3.1. General

Field connections of main members of trusses, arches, continuous beams, plate girders, bents, towers, and rigid frames shall be preassembled prior to erection as necessary to verify the geometry of the completed structure or unit and to verify or prepare field splices. Attaining accurate geometry is the responsibility of the Contractor and the Contractor shall propose an appropriate method of preassembly for approval by the Engineer. The method and details of preassembly shall be consistent with the erection procedure shown on the erection plans and camber diagrams prepared by the Contractor and approved by the Engineer. As a minimum, the preassembly procedure shall consist of assembling three contiguous panels accurately adjusted for line and camber. Successive assemblies shall consist of at least one section or panel of the previous assembly (repositioned if necessary and adequately pinned to assure accurate alignment) plus two or more sections or panels added at the advancing end. In the case of structures longer than 46 m, each assembly shall be not less than 46 m long regardless of the length of individual continuous panels or sections. At the option of the Fabricator, sequence of assembly may start from any location in the structure and proceed in one or both directions so long as the preceding requirements are satisfied.

At the discretion of the Engineer, if the pre-assembly procedure cause any damage to connections or any of the structural attachments, the affected part shall be replaced at the Contractor's expense.

13.5.3.2. Bolted Connections

For bolted connections, holes shall be prepared as outlined in Article 13.4.10 "Bolt Holes". Where applicable, major components shall be assembled with milled ends of compression members in full bearing and then shall have their subsized holes reamed to the specified size while the connections are assembled.

13.5.3.3. Check Assembly-Numerically-Controlled Drilling

When the Contractor opts to use numerically-controlled drilling, a check of assembly shall be required for each major structural type of each project, unless
otherwise designated in the contract documents, and shall consist of at least three contiguous shop sections or, in a truss, all members in at least three contiguous panels but not less than the number of panels associated with three contiguous chord lengths (i.e., length between field splices).

Check assemblies should be based on the proposed order of erection, joints in bearings, special complex points, and similar considerations.

If the check assembly fails in some specific manner to demonstrate that the required accuracy is being obtained, further check assemblies may be required by the Engineer for which there shall be no additional cost to the Owner.

Each assembly, including camber, alignment, accuracy of holes, and fit of milled joints, shall be approved by the Engineer before reaming is commenced or before an N/C drilled check assembly is dismantled.

13.5.3.4. Field-Welded Connections

For field-welded connections the fit of members including the proper space between abutting flanges shall be prepared or verified with the segment preassembled in accordance with Article 13.5.3.1.

13.5.4. Match-Marking

Connecting parts preassembled in the shop to assure proper fit in the field shall be match-marked, and a diagram showing such marks shall be furnished to the Engineer.

13.5.5. Connections Using Unfinished, Turned, or Ribbed Bolts

13.5.5.1. General

When unfinished bolts are specified, the bolts shall be unfinished, turned, or ribbed bolts conforming to the requirements for Grade A bolts of standard specification for carbon steel bolts and studs, ASTM A 307, 414 MPa tensile strength (carbon and alloy-steel externally threaded metric fasteners, ASTM F 568M, Property Class 4.6, 400-MPa tensile strength). Bolts shall have single self-locking nuts or double nuts unless otherwise specified in the contract documents. Beveled washers shall be used where bearing faces have a slope of more than 1:20 with respect to a plane normal to the bolt axis. The specifications of this Article do not pertain to the use of high-strength bolts. Bolted connections fabricated with high-strength bolts shall conform to Article 13.5.6, "Connections Using High-Strength Bolts."

13.5.5.2. Turned Bolts

The surface of the body of turned bolts shall meet the ANSI B46.1 roughness rating value of 3.2 µm. Heads and nuts shall be hexagonal with standard dimensions for bolts of the nominal size specified or the next larger nominal size. Diameter of threads shall be equal to the body of the bolt or the nominal diameter of the bolt specified. Holes for turned bolts shall be carefully reamed with bolts furnished to provide for a light driving fit. Threads shall be entirely outside of the holes. A washer shall be provided under the nut. Shop assemblies other than the check assemblies will not be required.

13.5.5.3. Ribbed Bolts

The body of ribbed bolts shall be of an approved form with continuous longitudinal ribs. The diameter of the body measured on a circle through the points of the ribs shall be 2 mm greater than the nominal diameter specified for the bolts.
Ribbed bolts shall be furnished with round heads conforming to ANSI B 18.5 (ANSI B 18.5.2.2M or B 18.5.2.3M) as specified. Nuts shall be hexagonal, either recessed or with a washer of suitable thickness. Ribbed bolts shall make a driving fit with the holes. The hardness of the ribs shall be such that the ribs do not distort to permit the bolts to turn in the holes during tightening. If for any reason the bolt twists before drawing tight, the hole shall be carefully reamed and an oversized bolt used as a replacement.

13.5.6. Connections Using High-Strength Bolts

13.5.6.1. General

This Article covers the assembly of structural joints using AASHTO M 164 (ASTM A 325) [(AASHTO M 164M (ASTM A 325M))] or AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) high-strength bolts or equivalent fasteners, installed so as to develop the minimum required bolt tension specified in Table 13.4. The bolts are used in holes conforming to the requirements of Article 13.4.10, "Bolt Holes".

13.5.6.2. Bolted Parts

All material within the grip of the bolt shall be steel; there shall be no compressible material such as gaskets or insulation within the grip. Bolted steel parts shall fit solidly together after the bolts are snugged and may be coated or uncoated. The slope of the surfaces of parts in contact with the bolt head or nut shall not exceed 1:20 with respect to a plane normal to the bolt axis.

13.5.6.3. Surface Conditions

At the time of assembly, all joint surfaces, including surfaces adjacent to the bolt head and nut, shall be free of scale, except tight mill scale, and shall be free of dirt or other foreign material. Burrs that would prevent solid seating of the connected parts in the snug condition shall be removed.

Paint is permitted on the faying surface including slip critical joints when designed in accordance with Article 6.13.2, "Bolted Connections," of the (MA-100-D-V2/2).

The contacting surfaces of slip-critical connections shall meet the requirements of the following paragraphs, as applicable:

- In non-coated joints, paint, including any inadvertent overspray, shall be excluded from areas closer than one bolt diameter but not less than 25 mm from the edge of any hole and all areas within the bolt pattern.

- Joints specified to have painted faying surfaces shall be blast cleaned and coated with a paint which has been qualified in accordance with requirements of Article 6.13.2.8, "Slip Resistance," of the (MA-100-D-V2/2).

- Coated joints shall not be assembled before the coating has cured for the minimum time used in the qualifying test.

- Faying surfaces specified to be galvanized shall be hot-dip galvanized in accordance with AASHTO M 111 M/M 111 (ASTM A 123/A 123M) and shall subsequently be roughened by means of hand wire brushing. Power wire brushing is not permitted.

13.5.6.4. Installation of Fasteners

1. General

Fastener components shall be assigned lot numbers, including rotational-capacity lot numbers, prior to shipping and components shall be assembled when installed. Such components shall be protected from dirt and moisture at the job site. Only the number of anticipated components to be installed and tensioned during a work shift shall be removed from protective storage. Components not used shall be returned to protective storage at the end of the shift. Assemblies for slip-critical connections which accumulate rust or dirt resulting from job site conditions shall be cleaned, relubricated, and tested for rotational capacity prior to installation. All galvanized nuts shall be lubricated with a lubricant containing a visible dye. Plain bolts must be oily to touch when delivered and installed. Lubricant on exposed surfaces shall be removed prior to painting.

A bolt-tension measuring device (a Skidmore-Wilhelm Calibrator or other acceptable bolt-tension indicating device) shall be at all job sites where high-strength bolts are being installed and tensioned. The tension-measuring device shall be used to perform the rotational-capacity test and to confirm:

- The suitability to satisfy the requirements of Table 13.4 of the complete fastener assembly, including lubrication if required to be used in the work,
- calibration of the wrenches, and
- the understanding and proper use by the bolting crew of the installation method.

To perform the calibrated wrench verification test for short grip bolts, direct tension indicators (DTI) with solid plates may be used in lieu of a tension-measuring device. The DTI lot shall be first verified with a longer grip bolt in the Skidmore-Wilhelm Calibrator or an acceptable equivalent device. The frequency of confirmation testing, the number of tests to be performed, and the test procedure shall be as specified in Articles 13.5.6.4.4 through 13.5.6.4.7, as applicable. The accuracy of the tension measuring device shall be confirmed by an approved testing agency at least annually.

Bolts and nuts together with washers of size and quality specified in the contract documents, located as required below, shall be installed in properly aligned holes and tensioned and inspected by any of the installation methods described in Articles 13.5.6.4.4 through 13.5.6.4.7 to at least the minimum tension specified in Table 13.2. Tensioning may be done by turning the bolt while the nut is prevented from rotating. When it is impractical to turn the nut, impact wrenches, if used, shall be of adequate capacity and sufficiently supplied with air to apply the proper tension to each bolt in approximately ten seconds.

AASHTO M 253 (ASTM A 490) [(AASHTO M 253M (ASTM A 490M))] fasteners and galvanized AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) fasteners shall not be reused. Other AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) bolts may be reused if approved by the Engineer. Touching up or retorquing previously tensioned bolts which may have been loosened by the tensioning of adjacent bolts shall not be considered as reuse provided the torquing continues from the initial position and does not require greater rotation, including the tolerance, than that required by Table 13.5.

Bolts shall be installed in all holes of the connection and the connection brought to a snug condition.
Snuggling shall progress systematically from the most rigid part of the connection to the free edges. The snugging sequence shall be repeated until the full connection is in a snug condition.

Table 13.4: Minimum Required Bolt Tension, kN

<table>
<thead>
<tr>
<th>Bolt Size (mm)</th>
<th>AASHTO M 164 ASTM A 325</th>
<th>AASHTO M 253 ASTM A 490</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>53.5</td>
<td>66.7</td>
</tr>
<tr>
<td>16</td>
<td>84.5</td>
<td>106.8</td>
</tr>
<tr>
<td>19</td>
<td>124.6</td>
<td>155.7</td>
</tr>
<tr>
<td>22</td>
<td>173.5</td>
<td>218</td>
</tr>
<tr>
<td>25</td>
<td>227</td>
<td>284.7</td>
</tr>
<tr>
<td>29</td>
<td>249</td>
<td>356</td>
</tr>
<tr>
<td>32</td>
<td>316</td>
<td>453.7</td>
</tr>
<tr>
<td>35</td>
<td>378</td>
<td>538.2</td>
</tr>
<tr>
<td>38</td>
<td>458</td>
<td>658.3</td>
</tr>
</tbody>
</table>

The minimum bolt tension shall be taken as seventy percent (70%) of specified minimum tensile strength of bolts (as specified in ASTM Specifications for tests of full-size A 325 (A 325M) and A 490 (A 490M) bolts with UNC threads (metric coarse thread series, ANSI B1.13M), loaded in axial tension) rounded to the nearest 1000 N.

Table 13.5: Nut Rotation from the Snug Condition

<table>
<thead>
<tr>
<th>Geometry of Outer Faces of Bolted Parts</th>
<th>Bolt length measured from underside of head to end of bolt.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both faces normal to bolt axis.</td>
<td>One face normal to bolt axis and other face sloped not more than 1:20. Bevel washer not used.</td>
</tr>
<tr>
<td>Both faces sloped not more than 1:20 from normal to bolt axis. Bevel washers not used.</td>
<td></td>
</tr>
</tbody>
</table>

| Up to and including four diameters     | 1/3 turn                     | 1/2 turn                     | 2/3 turn                     |
| Over four diameters, but not exceeding eight diameters | 1/2 turn                     | 2/3 turn                     | 5/6 turn                     |
| Over eight diameters, but not exceeding 12 diameters | 2/3 turn                     | 5/6 turn                     | 1 turn                       |

Rotation, as used in Table 13.5, shall be taken as relative to the bolt, regardless of the element (nut or bolt) being turned. The tolerances are minus 0, plus 30 degrees for bolts installed by a 1/2 turn or less; for bolts installed by 2/3 turn or more, the tolerance are minus 0, plus 45 degrees.
The values, given in Table 13.5, shall be applicable only to connections in which all material within grip of the bolt is steel.

For situations in which the bolt length measured from the underside of the head to the end of the bolt exceeds 12 diameters, the required rotation shall be determined by actual tests in a suitable tension device simulating the actual conditions.

2. Rotational-Capacity Tests

Rotational-capacity testing is required for all fastener assemblies. Assemblies specified as galvanized shall be tested after galvanizing. Washers shall be required as part of the test even though they may not be required as part of the installation procedure. The following shall apply:

- Except as modified herein, the rotational-capacity test shall be performed in accordance with the requirements of AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)).
- Each combination of bolt production lot, nut lot, and washer lot shall be tested as an assembly. Where washers are not required by the installation procedures, they need not be included in the lot identification.
- A rotational-capacity lot number shall have been assigned to each combination of lots tested.
- The minimum frequency of testing shall be two assemblies per rotational-capacity lot.
- For bolts that are long enough to fit in a Skidmore-Wilhelm Calibrator, the bolt, nut, and washer assembly shall be assembled in a Skidmore-Wilhelm Calibrator or an acceptable equivalent device.
- Bolts that are too short to test in a Skidmore-Wilhelm Calibrator may be tested in a steel joint. The tension requirement, in the section below, need not apply. The maximum torque requirement, torque ≤0.250PD, shall be computed using a value of P equal to the turn test tension taken as 1.15 times the bolt tension in Table 13.4.
- The tension reached at the rotation below, i.e., the turn-test tension, shall be equal to or greater than 1.15 times the required fastener tension, i.e., installation tension, shown in Table 13.4.
- In a tension-measuring device, the minimum rotation from an initial tension of ten percent of the minimum required tension shall be two times the required number of turns indicated in Table 13.5 without stripping or failure.

After the required installation tension listed above has been exceeded, one reading of tension and torque shall be taken and recorded. The torque value shall conform to the following:

\[ \text{Torque} \leq 0.250PD \]

Where:

\[ \text{Torque} = \text{measured torque, N.mm.} \]
\[ P = \text{measured bolt tension, N.} \]
\[ D = \text{bolt diameter, mm.} \]

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3. Requirement for Washers

Where the outer face of the bolted parts has a slope greater than 1:20 with respect to a plane normal to the bolt axis, a hardened bevelled washer shall be used to compensate for the lack of parallelism.

Hardened bevelled washers for American Standard Beams and Channels shall be required and shall be square or rectangular, shall conform to the requirements of AASHTO M 293 (ASTM F 436) [(AASHTO M 293M (ASTM F 436M))], and shall taper in thickness.

Where necessary, washers may be clipped on one side to a point not closer than 0.875 times the bolt diameter from the center of the washer.

Hardened washers are not required for connections using AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) and AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) bolts, except as follows:

- Hardened washers shall be used under the turned element when tensioning is to be performed by calibrated wrench method.

- Irrespective of the tensioning method, hardened washers shall be used under both the head and the nut when AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) bolts are to be installed in material having a specified yield point less than 275 MPa. When DTIs are used, they may replace a hardened washer provided a standard sized hole is used.

- Where AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) bolts of any diameter or AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) bolts equal to or less than 24 mm in diameter are to be installed in oversize or short-slotted holes in an outer ply, a hardened washer conforming to AASHTO M 293 (ASTM F 436) (AASHTO M 293M (ASTM F 436M)) shall be used.

- Where AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) bolts over 24 mm in diameter are to be installed in an oversize or short-slotted hole in an outer ply, hardened washers conforming to AASHTO M 293 (ASTM F 436) (AASHTO M 293M (ASTM F 436M)), except with 8 mm minimum thickness, shall be used under both the head and the nut in lieu of standard thickness hardened washers. Multiple hardened washers with combined thickness equal to or greater than 8 mm shall not be considered as satisfying this requirement.

- Where AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) bolts of any diameter or AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) bolts equal to or less than 24 mm in diameter are to be installed in a long slotted hole in an outer ply, a plate washer or continuous bar of at least 8 mm thickness with standard holes shall be provided. These washers or bars shall have a size sufficient to completely cover the slot after installation and shall be of structural grade material, but need not be hardened, except as follows.

- Where AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) bolts over 24 mm in diameter are to be used in long slotted holes in external plies, a single hardened washer conforming to AASHTO M 293 (ASTM F 436) (AASHTO M 293M (ASTM F 436M)), but with 8 mm minimum thickness shall be used in lieu of washers or bars of structural grade material. Multiple hardened washers with combined thickness equal to or greater than 8 mm shall not be considered as satisfying this requirement.
Alternate design fasteners meeting the requirements of Article 13.3.2.6, "Load Indicator Devices," with a geometry which provides a bearing circle on the head or nut with a diameter equal to or greater than the diameter of hardened washers meeting the requirements of AASHTO M 293 (ASTM F 436) (AASHTO M 293M (ASTM F 436M)) satisfy the requirements for washers specified herein and may be used without washers.

4. Turn-of-Nut installation Method

When the turn-of-nut installation method is used, hardened washers are not required, except as may be specified in Article 13.5.6.4.3.

Verification testing using a representative sample of not less than three fastener assemblies of each diameter, length, and grade to be used in the work shall be performed at the start of work in a device capable of indicating bolt tension. This verification test shall demonstrate that the method used by the bolting crew to develop a snug condition and to control the turns from a snug condition develops a tension not less than five percent greater than the tension required by Table 13.4. Periodic retesting shall be performed when ordered by the Engineer.

After snugging, the applicable amount of rotation specified in Table 13.5 shall be achieved. During the tensioning operation there shall be no rotation of the part not turned by the wrench. Tensioning shall progress systematically from the most rigid part of the joint to its free edges.

5. Calibrated Wrench Installation Method

The calibrated wrench method may be used only when wrenches are calibrated on a daily basis and when a hardened washer is used under the turned element. Standard torques determined from tables or from formulas which are assumed to relate torque to tension shall not be acceptable.

When calibrated wrenches are used for installation, they shall be set to deliver a torque which has been calibrated to produce a tension not less than five percent in excess of the minimum tension specified in Table 13.4. The installation procedures shall be calibrated by verification testing at least once each working day for each fastener assembly that is being installed in the work that day. This verification testing shall be accomplished in a tension-measuring device capable of indicating actual bolt tension by testing three typical fastener assemblies from each lot. Bolts, nuts, and washers under the turned element shall be sampled from production lots. Wrenches shall be recalibrated when a significant difference is noted in the surface condition of the bolts, threads, nuts, or washers. It shall be verified during actual installation in the assembled steel work that the wrench adjustment selected by the calibration does not produce a nut or bolt head rotation from snug condition greater than that permitted in Table 13.5. If manual torque wrenches are used, nuts shall be torqued in the tensioning direction when torque is measured.

When calibrated wrenches are used to install and tension bolts in a connection, bolts shall be installed with hardened washers under the turned element. Following snugging, the connection shall be tensioned using the calibrated wrench. Tensioning shall progress systematically from the most rigid part of the joint to its free edges. The wrench shall be returned to "touch up" previously tensioned bolts which may have been relaxed as a result of the subsequent tensioning of adjacent bolts until all bolts are tensioned to the prescribed amount.
6. Alternative Design Bolt Installation Method

When fasteners which incorporate a design feature intended to indirectly indicate that the applied torque develops the required bolt tension or to automatically develop the tension required by Table 13.4 and which have been qualified under Article 13.3.2.5, "Alternative Fasteners," are to be installed, verification testing using a representative sample of not less than three fastener assemblies of each diameter, length and grade to be used in the work shall be performed at the job site in a device capable of indicating bolt tension. The test assembly shall include flat-hardened washers, if required in the actual connection, arranged as in the actual connections to be tensioned. The verification test shall demonstrate that each bolt develops a tension not less than five percent greater than the tension required by Table 13.4. The Manufacturer's installation procedure shall be followed for installation of bolts in the calibration device and in all connections. Periodic retesting shall be performed when ordered by the Engineer.

When alternative design fasteners, which are intended to control or indicate bolt tension of the fasteners are used, bolts shall be installed in all holes of the connection and initially snugged sufficiently to bring all plies of the joint into firm contact, but without yielding or fracturing the control or indicator element of the fasteners. All fasteners shall then be further tensioned, progressing systematically from the most rigid part of the connection to the free edges in a manner that will minimize relaxation of previously tensioned bolts. In some cases, proper tensioning of the bolts may require more than a single cycle of systematic partial tensioning prior to final yielding or fracturing of the control or indicator element of individual fasteners. If yielding or fracture occurs prior to the final tensioning cycle, the individual fastener assembly shall be replaced with a new one.

7. Direct Tension Indicator Installation Method

When Direct Tension Indicators (DTIs) meeting the requirements of Article 13.3.2.6 are used with high-strength bolts to indicate bolt tension, they shall be subjected to the verification testing described below and installed in accordance with the method specified below. Unless otherwise approved by the Engineer, the DTIs shall be installed under the head of the bolt and the nut turned to tension the bolt. The Manufacturer's recommendations shall be followed for the proper orientation of the DTI and additional washers, if any, required for the correct use of the DTI. Installation of a DTI under the turned element may be permitted if a washer is used to separate the turned element from the DTI.

a. Verification

Verification testing shall be performed in a calibrated bolt-tension measuring device. A special flat insert shall be used in place of the normal bolt head holding insert. Three verification tests shall be required for each combination of fastener assembly rotational-capacity lot, DTI lot, and DTI position relative to the turned element (bolt head or nut) to be used on the project. The fastener assembly shall be installed in the tension-measuring device with the DTI located in the same position as in the work. The element intended to be stationary (bolt or nut) shall be restrained from rotation.

The verification tests shall be conducted in two stages. The bolt nut and DTI assembly shall be installed in a manner so that at least three and preferably not more than five threads are located between the bearing face of the nut and the bolt head. The
bolt shall be tensioned first to the load equal to that listed in Table 13.6 under Verification Tension for the grade and diameter of the bolt. If an impact wrench is used, the tension developed using the impact wrench shall be no more than two-thirds of the required tension. Subsequently, a manual wrench shall be used to attain the required tension. The number of refusals of the 0.125 mm tapered feeler gage in the spaces between the protrusions shall be recorded. The number of refusals for uncoated DTIs under the stationary or turned element, or coated DTIs under the stationary element, shall not exceed the number listed under Maximum Verification Refusals in Table 13.6 for the grade and diameter of bolt used. The maximum number of verification refusals for coated DTIs (galvanized, painted, or epoxy-coated), when used under the turned element, shall be no more than the number of spaces on the DTI less one. The DTI lot shall be rejected if the number of refusals exceeds the values in the table or, for coated DTIs if the gage is refused in all spaces.

After the number of refusals is recorded at the verification load, the bolt shall be further tensioned until the 0.125 mm feeler gage is refused at all the spaces and a visible gap exists in at least one space. The load at this condition shall be recorded and the bolt removed from the tension-measuring device. The nut shall be able to be run down by hand for the complete thread length of the bolt excluding thread run-out. If the nut cannot be run down for this thread length, the DTI lot shall be rejected unless the load recorded is less than 95 percent of the average load measured in the rotational capacity test of the fastener lot as specified in Article 13.5.6.4.2, "Rotational-Capacity Tests".

If the bolt is too short to be tested in the calibration device, the DTI lot shall be verified on a long bolt in a calibrator to determine the number of refusals at the verification tension listed in Table 13.6. The number of refusals shall not exceed the values listed under maximum verification refusals in Table 13.6. Another DTI from the same lot shall then be verified with the short bolt in a convenient hole in the work. The bolt shall be tensioned until the 0.125 mm feeler gage is refused in all spaces and a visible gap exists in at least one space. The bolt shall then be removed from the tension-measuring device and the nut shall be able to be run down by hand for the complete thread length of the bolt excluding thread run-out. The DTI lot shall be rejected if the nut cannot be run down this thread length.

### Table 13.6: Direct Tension Indicator Requirements.

<table>
<thead>
<tr>
<th>Bolt Size, mm.</th>
<th>Verification Tension, kN</th>
<th>Maximum Verification Refusals</th>
<th>DTI Spaces</th>
<th>Minimum Installation Refusals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A 325</td>
<td>A 490</td>
<td>A 325</td>
<td>A 490</td>
</tr>
<tr>
<td>13</td>
<td>57.8</td>
<td>71.2</td>
<td>1</td>
<td>2</td>
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<td>16</td>
<td>89</td>
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<td>19</td>
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<td>2</td>
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<td>25</td>
<td>240.2</td>
<td>298</td>
<td>2</td>
<td>3</td>
</tr>
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<td>29</td>
<td>262.4</td>
<td>373.7</td>
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<td>3</td>
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<td>396</td>
<td>564</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>38</td>
<td>480.4</td>
<td>689.5</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
b. Installation

Installation of fastener assemblies using DTIs shall be performed in two stages. The stationary element shall be held against rotation during each stage of the installation. The connection shall be first snugged with bolts installed in all the holes of the connection and tensioned sufficiently to bring all the plies of the connection into firm contact. The number of spaces in which a 0.125 mm feeler gage is refused in the DTI after snugging shall not exceed those listed under Maximum Verification Refusals in Table 13.6. If the number exceeds the values in the table, the fastener assembly shall be removed and another DTI installed and snugged.

For uncoated DTIs used under a stationary or turned element and for coated DTIs used under stationary element, the bolts shall be further tensioned until the number of refusals of the 0.125 mm feeler gage shall be equal to or greater than the number listed under Minimum Installation Refusals in Table 13.6. If the bolt is tensioned so that no visible gap in any space remains, the bolt and DTI shall be removed and replaced by a new properly tensioned bolt and DTI.

When coated DTIs (galvanized, painted, or epoxy coated) are used under a turned element, the 0.125 mm feeler gage shall be refused in all spaces.

8. Lock-Pin and Collar Fasteners

The installation of lock-pin and collar fasteners shall be by methods and procedures approved by the Engineer.

9. Inspection

a. General

The Engineer shall determine that the requirements of Articles 13.5.6.4.9.b and 13.5.6.4.9.c following, are met in the work.

b. Responsibilities of the Engineer

Before the installation of fasteners in the work, the Engineer shall:

- check the marking, surface condition, and storage of bolts, nuts, washers, and DTIs, if used, and the faying surfaces of joints for compliance with the requirements of Articles 13.3.2, 13.5.6.1, and 13.5.6.4.1 and
- observe calibration and/or testing procedures required in Articles 13.5.6.4 through 13.5.6.4.7, as applicable, to confirm that the selected procedure is properly used and that, when so used with the fastener assemblies supplied, the tensions specified in Table 13.4 are developed.

The Engineer shall monitor the installation of fasteners in the work to assure that the selected installation method, as demonstrated in the initial testing to develop the specified tension, is routinely followed.

c. Inspection Procedures

Either the Engineer or the Contractor, in the presence of the Engineer at the Engineer's option, shall inspect the tensioned bolts using an inspection torque wrench, unless alternate fasteners or direct tension indicator devices are used, allowing verification by other methods. Inspection tests should be conducted prior to possible loss of lubrication or corrosion influence on tightening torque.
Three fastener assembly lots in the same condition as those under inspection shall be placed individually in a device calibrated to measure bolt tension. This calibration operation shall be done at least once each inspection day. There shall be a washer under the turned element in tensioning each bolt if washers are used on the structure. If washers are not used on the structure, the material used in the tension-measuring device which abuts the part turned shall be of the same specification as that used on the structure. In the calibrated device, each bolt shall be tensioning by any convenient means to the specified tension. The inspecting wrench shall then be applied to the tensioned bolt to determine the torque required to turn the nut or head five degrees (25 mm at a 300 mm radius) in the tensioning direction. The average of the torque required for all three bolts shall be taken as the job-inspection torque.

Ten percent (at least two) of the tensioned bolts on the structure represented by the test bolts shall be selected at random in each connection. The job-inspection torque shall then be applied to each with the inspecting wrench turned in the tensioning direction. If this torque turns no bolt head or nut, the bolts in the connection shall be considered to be properly tensioned. If the torque turns one or more boltheads or nuts, the job-inspection torque shall then be applied to all bolts in the connection. Any bolt whose head or nut turns at this stage shall be retorqued and reinspected. The Contractor may, however, retorque all the bolts in the connection and resubmit it for inspection, so long as DTIs are not over tensioned and fastener assemblies are not damaged.

13.5.7. Welding

Welding, welder qualifications, prequalification of weld details, and inspection of welds shall conform to the requirements of the current AASHTO/ A WS D 1.5M/D 1.5 Bridge Welding Code.

Brackets, clips, shipping devices, or other material not required by the contract documents shall not be welded or tacked to any member unless specified in the contract documents and approved by the Engineer.

13.6. Erection

13.6.1. General

The Contractor shall provide all tools, machinery, and equipment necessary to erect the structure.

Falsework and forms shall be in accordance with the requirements of Section 6, "Temporary Works."

13.6.2. Handling and Storing Materials

Material to be stored at the job site shall be placed on skids above the ground. It shall be kept clean and properly drained. Girders and beams shall be placed upright and shored. Long members, such as columns and chords, shall be supported on skids placed near enough together to prevent damage from deflection. If the contract documents are for erection only, the Contractor shall check the material received against the shipping lists and report promptly in writing any shortage or injury discovered. After material is received by the Contractor, the Contractor shall be responsible for any damage to or loss of material.
13.6.3. Bearings and Anchorages
Bridge bearings shall be furnished and installed in conformance with Section 16, "Bearing Devices".

If the steel superstructure is to be placed on a substructure that was built under a separate contract, the Contractor shall verify that the masonry has been constructed in the right location and to the correct lines and elevations before ordering materials.

13.6.4. Erection Procedure

13.6.4.1. Conformance to Drawings
The erection procedure shall conform to the erection drawings submitted in accordance with Article 13.2.3. Any modifications to or deviations from this erection procedure shall require revised drawings and verification of stresses and geometry.

13.6.4.2. Erection Stresses
Any erection stresses induced in the structure as a result of using a method of erection which differs from the contract documents shall be accounted for by the Contractor. Erection design calculations for such changed methods shall be prepared at the Contractor's expense and submitted to the Engineer. The calculations shall indicate any change in stresses or change in behavior for the temporary and final structures. Additional material required to keep both the temporary and final stresses within the allowable limits used in design shall be provided at the Contractor's expense.

The Contractor shall be responsible for providing temporary bracing or stiffening devices to accommodate handling stresses in individual members or segments of the structure during erection. When the partial structure is deemed prone to suitability concerns, the contractor shall provide the requisite calculations showing that the partial structure will remain stable until the complete continuity of the structure is reached.

13.6.4.3. Maintaining Alignment and Camber
During erection, the Contractor shall be responsible for supporting segments of the structure in a manner that will produce the proper alignment and camber in the completed structure. Cross frames and diagonal bracing shall be installed as necessary during the erection process to provide stability and assure correct geometry. Temporary bracing, if necessary at any stage of erection, shall be provided by the Contractor.

13.6.5. Field Assembly
The parts shall be accurately assembled as specified in the contract documents or erection drawings and any match-marks shall be followed. The material shall be carefully handled so that no parts will be bent, broken, or otherwise damaged. Hammering which will injure or distort the members shall not be done. Bearing surfaces and surfaces to be in permanent contact shall be cleaned before the members are assembled. Splices and field connections shall have one-half of the holes filled with bolts and cylindrical erection pins (half bolts and half pins) before installing and tightening the balance of high-strength bolts. Splices and connections carrying traffic during erection shall have three-fourths of the holes so filled.

Fitting-up bolts may be the same high-strength bolts used in the installation. If other fitting-up bolts are used, they shall be of the same nominal diameter as the high-strength bolts and cylindrical erection pins shall be 0.8 mm larger.
13.6.6. Pins Connections
Pilot and driving nuts shall be used in driving pins. They shall be furnished by the Contractor without charge. Pins shall be so driven that the members will take full bearing on them. Pin nuts shall be screwed up tight and the threads burr ed at the face of the nut with a pointed tool.

13.6.7. Misfits
The correction of minor misfits involving minor amounts of reaming, cutting, grinding, and chipping shall be considered a legitimate part of the erection. However, any error in the shop fabrication or deformation resulting from handling and transporting shall cause for rejection.

The Contractor shall be responsible for all misfits, errors, and damage and shall make the necessary corrections and replacements.

13.7. Expansion Joints
Expansion joints shall be fabricated in accordance with the requirements of this section. Install expansion joints in accordance with the requirements of Section 17, "Bridge Deck Joint Seals".

Complete working drawings for fabrication and installation of expansion joints shall be submitted. The Contractor shall include the joint manufacturer’s instructions for proper installation of the joint on the drawings. Joint opening dimension for an ambient temperature of fifteen degree Celsius (15°C) and adjustments to that dimension due to temperature variations shall be shown.

The Contractor shall fabricate expansion joints accurately to conform to the specified concrete floor section, matching cross slopes and break points. Expansion joints shall be assembled and checked for fit in the shop, then it shall be match marked for shipment.

For sealed expansion joints, the steel receptors shall be fabricated to be continuous the full length of joint including 150 mm extensions. The number of splices in the steel receptor shall be minimized. To splice, a partial penetration weld, ground smooth shall be used. Welding shall not be done in areas in contact with the neoprene.

The Contractor shall provide and install a neoprene gland continuous the full length of joint including 150 mm extensions. At locations where joints are shown to be for skew of thirty-five degree (35°) and greater, the neoprene shall be spliced by vulcanizing or other approved method that provides strength and durability equal to unspliced neoprene. Splices shall be permanently watertight.

13.8. Works Acceptance

13.8.1. Quality Control
Material (except bearing devices and painting) for steel structures should be evaluated according to the article 3.6.1. Furnish production certifications for each shipment of structural steel, steel forgings, and high-strength bolts, nuts, and washers, should be available for quality control measurements. Construction of steel structures should be evaluated according to the article 3.5.1. Bearing devices should be evaluated according to the section 16. Painting should be evaluated according to the section 15.
13.8.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of steel structure work, by reviewing the test reports and manufacturing certificates coming with the importing materials, and are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that insure the quality of steel structure according to the previous sections and Table 13.12.

13.9. Measurement and Payment

13.9.1. Method of Measurement

Pay quantities for each type of steel and iron will be measured by kilogram, computed from dimensions shown in the contract documents using the following rules and assumptions in Table 13.7.

Table 13.7: Unit Weights of Steel and Iron.

<table>
<thead>
<tr>
<th>Unit Weights, kN/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cast Iron</td>
</tr>
<tr>
<td>Malleable Iron</td>
</tr>
<tr>
<td>Wrought Iron</td>
</tr>
<tr>
<td>Steel-Rolled or Cast</td>
</tr>
</tbody>
</table>

The weight of rolled shapes shall be computed on the basis of their nominal weight per meter as specified in the contract documents or as listed in AISC handbooks.

The mass of plates shall be computed on the basis of the nominal mass for their width and thickness as specified in the contract documents, plus an estimated overrun computed as one-half the "Permissible Variation in Thickness and Weight" as tabulated in "General Requirements for Delivery of Rolled Steel Plates, Shapes, Steel Piling, and Bars for Structural Use, AASHTO M160M/M 160 (ASTM A 6/A 6M)."

The mass of castings shall be computed from the dimensions shown on the approved shop drawings, deducting for open holes and intrusion. To this mass shall be added five percent allowance for fillets and overrun. Scale mass may be substituted for computed mass in the case of castings or of small complex parts for which accurate computations of mass would be difficult.

The mass of temporary erection bolts, shop and field paint, boxes, crates, and other containers used for shipping; and materials used for supporting members during transportation and erection, will not be included.

The mass of any additional material required by Article 13.6.4.2, "Erection Stresses," to accommodate erection stresses resulting from the Contractor's choice of erection methods will not be included.

In computing pay mass on the basis of computed net mass the following stipulations in addition to those in the foregoing paragraphs shall apply:

- The mass shall be computed on the basis of the net finished dimensions of the parts as specified in the contract documents, deducting for copes, cuts, clips, and all open holes, except bolt holes.
The mass of heads, nuts, single washers, and threaded stick-through of all high tensile strength bolts, both shop and field, shall be included on the basis of the following mass as specified in Table 13.8.

- The mass of fillet welds shall be as specified in Table 13.9.
- To determine the pay quantities of galvanized metal, the mass to be added to the calculated mass of base metal for the galvanizing will be determined from the mass of zinc coatings specified by AASHTO M IIIM/M III (ASTM A 123/A 123M).
- No allowance will be made for the mass of paint.

**Table 13.8: Weight per 100 Bolts**

<table>
<thead>
<tr>
<th>Diameter of Bolt (mm)</th>
<th>Weight per 100 Bolts (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>88</td>
</tr>
<tr>
<td>16</td>
<td>141</td>
</tr>
<tr>
<td>19</td>
<td>233</td>
</tr>
<tr>
<td>22</td>
<td>358</td>
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<tr>
<td>25</td>
<td>519</td>
</tr>
<tr>
<td>29</td>
<td>735</td>
</tr>
<tr>
<td>32</td>
<td>943</td>
</tr>
<tr>
<td>35</td>
<td>1246</td>
</tr>
<tr>
<td>38</td>
<td>1512</td>
</tr>
</tbody>
</table>

**Table 13.9: Weight of Fillet Welds**

<table>
<thead>
<tr>
<th>Size of Fillet Weld (mm)</th>
<th>Weight (N/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.8</td>
<td>1.17</td>
</tr>
<tr>
<td>6.4</td>
<td>2.0</td>
</tr>
<tr>
<td>7.9</td>
<td>3.2</td>
</tr>
<tr>
<td>9.5</td>
<td>4.4</td>
</tr>
<tr>
<td>12.7</td>
<td>8.0</td>
</tr>
<tr>
<td>15.9</td>
<td>11.7</td>
</tr>
<tr>
<td>19.1</td>
<td>16.1</td>
</tr>
<tr>
<td>22.2</td>
<td>22.0</td>
</tr>
<tr>
<td>25.4</td>
<td>29.2</td>
</tr>
</tbody>
</table>

**13.9.2. Basis of Payment**

The contract-documents price for fabrication and erection of structural steel shall be considered to be full compensation for the cost of all labor, equipment, materials, transportation, and shop and field painting, if not otherwise provided for, necessary for the proper completion of the work in accordance with the contract documents. The contract-documents price for fabrication without erection shall be considered to be full compensation for the cost of all labor, equipment, and materials necessary for the proper completion of the work, other than erection and field assembly, in accordance with the contract documents.

Under contract documents containing an item for structural steel, all metal parts other than metal reinforcement for concrete, such as anchor bolts and nuts, shoes, rockers, rollers, bearing and slab plates, pins and nuts, expansion dams, roadway drains
and scuppers, weld metal, bolts embedded in concrete, cradles and brackets, railing, and railing pots shall be paid for as structural steel unless otherwise stipulated.

Payment will be made on a mass unit-price or a lump-sum basis as required by the terms of the contract documents but, unless stipulated otherwise, it shall be on a mass unit-price basis. For members comprising both carbon steel and other special steel or material, when separate unit prices are provided for same, the mass of each class of steel in each such member shall be separately computed and paid for at the contract-documents unit price therefore.

Full-size members which are tested in accordance with the contract documents, when such tests are required by the contract documents, shall be paid for at the same rate as for comparable members for the structure. The cost of testing including equipment, labor, and incidentals shall be included in the contract-documents price for structural steel. Members which fail to meet the contract-documents requirements and members rejected as a result of tests will not be paid for by the Owner.

Payment will be made under one or more of the items in Table 13.10 and the quality control requirements for steel structures are shown in Table 13.11.

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.3.1</td>
<td>Structural Steel</td>
<td>kilogram</td>
</tr>
<tr>
<td>13.3.2</td>
<td>High-Strength Fasteners</td>
<td>kilogram</td>
</tr>
<tr>
<td>13.3.3</td>
<td>Welded Stud Shear Connectors</td>
<td>kilogram</td>
</tr>
<tr>
<td>13.3.4</td>
<td>Steel Forgings and Steel Shafting</td>
<td>kilogram</td>
</tr>
<tr>
<td>13.3.5</td>
<td>Steel Castings</td>
<td>kilogram</td>
</tr>
<tr>
<td>13.3.6</td>
<td>Iron Castings</td>
<td>kilogram</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance</td>
<td>Material for steel structures</td>
<td>Visual Inspection and Certification</td>
<td>-------</td>
<td>------</td>
<td>Article 13.3 and 3.5.1</td>
</tr>
<tr>
<td>Construction of steel structures</td>
<td>Visual Inspection and Measured</td>
<td>-------</td>
<td>------</td>
<td>Article 13.8 and 3.5.1</td>
<td></td>
</tr>
</tbody>
</table>
Table 13.12: AASHTO and ASTM designation and its title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>as specified</td>
<td>AASHTO M 270M/M 270</td>
<td>ASTM A 709/A 709M</td>
<td>Standard Specification for Structural Steel for Bridges</td>
</tr>
<tr>
<td>as specified</td>
<td></td>
<td>ASTM A 501</td>
<td>Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing</td>
</tr>
<tr>
<td>as specified</td>
<td></td>
<td>ASTM A 500, Grade B</td>
<td>Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 164</td>
<td>ASTM A 325</td>
<td>Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 253M</td>
<td>ASTM A 490M</td>
<td>Standard Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints Metric</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 293M</td>
<td>ASTM F 436M</td>
<td>Standard Specification for Hardened Steel Washers [Metric]</td>
</tr>
<tr>
<td>as specified</td>
<td></td>
<td>ASTM F 959M</td>
<td>Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 253</td>
<td>ASTM A490 - 08b</td>
<td>Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 298</td>
<td>ASTM B695 - 04</td>
<td>Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel</td>
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<tr>
<td>as specified</td>
<td>AASHTO M 232M/M 232</td>
<td>ASTM A153 / A153M - 09</td>
<td>Standard Specification for Zinc Coating Hot-Dip on Iron and Steel Hardware</td>
</tr>
<tr>
<td>as specified</td>
<td></td>
<td>ASTM F 1852</td>
<td>Standard Specification for Twist Off Type Tension Control Structural Bolt/Nut/Washer Assemblies, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 169</td>
<td>ASTM A108 - 07</td>
<td>Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished</td>
</tr>
<tr>
<td>as specified</td>
<td></td>
<td>ASTM A 109/A 109M</td>
<td>Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 102M/M 102</td>
<td>ASTM A 668/A 668M</td>
<td>Standard Specification for Magnetic Particle Examination of Large Crankshaft Forgings</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 169</td>
<td>ASTM A 108</td>
<td>Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM A 7811 A 781 M</td>
<td>Standard Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use</td>
<td></td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 103M/M 103</td>
<td>ASTM A27 / A27M - 08</td>
<td>Standard Specification for Steel Castings, Carbon, for General Application</td>
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<tr>
<td>as specified</td>
<td>ASTM A 481 A 48M</td>
<td>Standard Specification for Chromium Metal</td>
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<tr>
<td>as specified</td>
<td>ASTM A 536</td>
<td>Standard Specification for Ductile Iron Castings</td>
<td></td>
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<tr>
<td>as specified</td>
<td>ASTM A 47/A 47M</td>
<td>Standard Specification for Ferritic Malleable Iron Castings</td>
<td></td>
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<tr>
<td>as specified</td>
<td>AASHTO M 111M/M 111</td>
<td>ASTM A123 / A123M - 09</td>
<td>Standard Specification for Zinc Hot-Dip Galvanized Coatings on Iron and Steel Products</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 232M/M 232</td>
<td>ASTM A153 / A153M - 09</td>
<td>Standard Specification for Zinc Coating Hot-Dip on Iron and Steel Hardware</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM A 325M</td>
<td>Standard Specification for Structural Castings, Steel, Heat Treated 830 MPa Minimum Tensile Strength [Metric]</td>
<td></td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 253M</td>
<td>ASTM A490 - 08</td>
<td>Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 ksi Minimum Tensile Strength</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM A 490M</td>
<td>Standard Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints Metric</td>
<td></td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 293M</td>
<td>ASTM F 436M</td>
<td>Standard Specification for Hardened Steel Washers [Metric]</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 160M/M 160</td>
<td>ASTM A6 / A6M - 09</td>
<td>Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M IIIM/M III</td>
<td>ASTM A964 / A964M - 03</td>
<td>Standard Specification for Corrugated Steel Box Culverts</td>
</tr>
</tbody>
</table>
13.10. References
AASHTO/AWS D1.5M/D1.5- "Bridge Welding Code"-2002

OKLAHOMA. “Oklahoma Department of Transportation Standard Specifications for Highway Construction” Sec. 506


FHWA: "Standard Specifications For Construction of Roads and Bridges on Federal Highway Projects"- FP 03. Sec. 553.


MOT KSA;"General Specifications For Road And Bridge Construction"- November 1998- Sec. 5.05.

SECTION 14. STEEL GRID FLOORING

14.1. General

14.1.1. Description

This work shall consist of furnishing and installing steel grid flooring of the open type or of the concrete-filled type, as specified in the contract documents. When the Contractor is allowed to select any details of the design, said details shall meet the requirements for the design of steel grid floors specified in Articles 4.6.2.1 and 7.8.2 of the (MA-100-D-V1/2 & V2/2).

14.1.2. Working Drawings

The Contractor shall submit complete working drawings with assembly details to the Engineer for approval. Fabrication or construction of the flooring shall not be started until the drawings have been approved. Such approval shall not relieve the Contractor of any responsibility under the contract documents for the successful completion of the work.

14.2. Materials

14.2.1. Steel

All steel shapes, plates, and bars shall conform to AASHTO M 270M/M 270 (ASTM A 709/A 709M) Grade 36, 50, or 50W (Grade 250, 345, or 345W). Unless the material is galvanized or epoxy-coated, it shall have a copper content of 0.2 percent.

Reinforcing steel shall conform to the requirements of Section 11, "Reinforcing Steel."

14.2.2. Protective Treatment

Open-type floors, unless otherwise specified, shall be galvanized in accordance with the requirements of AASHTO M 111M/M 111 (ASTM A 123/A 123M).

Filled or partially filled types, specified in the contract documents, shall be either galvanized, painted, epoxy coated, or supplied in unpainted weathering steel.

If painted, the paint shall be applied according to the specifications for "Painting" except that dipping will be permitted. The paint shall be as specified for metal structures unless paint or coating of another type is required by the contract documents. When painting is specified, those areas of steel grid flooring completely encased in concrete may remain unpainted, unless otherwise specified in the contract documents.

14.2.3. Concrete

All concrete in filled steel grid floors shall conform to the requirements of Section 10, "Concrete Structures". The concrete and the size of aggregate shall be as specified for Class C concrete in Article 10.3 in Section 10, “Concrete Structures”.

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14.2.4. Skid Resistance
The upper edges of all members forming the wearing surface of open-type grid flooring shall be serrated to give the maximum skid resistance.

Concrete-filled or overlayed grid floors shall be given a skid-resistant texture as specified in Article 10.12.2, "Roadway Surface Finish" in Section 10.

14.3. Arrangement of Sections
All steel shall be straight and true to line and shall be assembled in a workmanlike manner.

Where the main elements are normal to centerline of roadway, the units generally shall be of such length as to extend over the full width of the roadway for roadways up to 12 m but in every case the units shall extend over at least three panels. Where joints are required, the ends of the main floor members shall be welded at the joints over their full cross-sectional area or otherwise connected to provide full continuity.

Where the main elements are parallel to centerline of roadway, the sections shall extend over not less than three panels and the ends of abutting units shall be welded over their full cross-sectional area or otherwise connected to provide full continuity in accordance with the design.

14.4. Provision For Camber
Unless otherwise specified in the contract documents, provision for camber shall be made as follows:

Steel units so rigid that they will not readily follow the required camber shall be cambered in the shop. For grid flooring types other than those employing a field placed full depth concrete filling attached to the deck with welded shear connectors, the stringers shall be canted or provided with shop-welded beveled bearing bars to provide a bearing surface parallel to the crown of the roadway. If beveled bars are used, they shall be continuous and fillet-welded along the centerline of the stringer flange, in which case, the design span length shall be governed by the width of the bearing bar instead of the width of the stringer flange.

Longitudinal stringers, except as provided in the following paragraph, shall be mill cambered or provided with bearing strips so that the completed floor after dead load deflection will conform to the longitudinal camber specified in the contract documents.

Vertical adjustment of full-depth-filled grid floors that are to be connected to supporting members with shear connectors may be accomplished by use of adjusting bolts operating through nuts welded to the grid and bearing on the top flange of framing members. Alternatively, shims may be used, and shims must be used if construction vehicles are to be allowed on the floor prior to final attachment.

14.5. Field Assembly
Areas of considerable size shall be placed and, if necessary, adjusted to proper fit before the floor is connected to its supports. Care shall be taken during lifting and placing to avoid overstressing the grid units. The main elements shall be made continuous as specified in Article 14.3, "Arrangement of Sections", and sections shall be connected together along their edges by welding or bolting in accordance with the contract documents. Connections shall be approved by the Engineer.
14.6. Connection to Supports

Except when other connection methods are specified in the contract documents or approved, the floor shall be connected to its steel supports by welding every fourth main element to the supporting member; however, welds shall be spaced no greater than 400 mm on centers. Before any welding is done, the floor shall either be temporarily loaded or it shall be clamped down to make a tight joint with full bearing. To minimize the stresses induced through clamping down, any differential elevation of 6 mm or more over 1200 mm supporting member shall be shimmed before welding the shim, the grid, and the supporting member. The location, length, and size of the welds shall be subject to the approval of the Engineer, but in no case shall they be less than the manufacturer’s standards.

Around the perimeter of continuous units of grid flooring, the ends of all main steel members of the flooring shall be securely fastened together by means of steel plates or angles welded to the ends of the main members or by thoroughly encasing the ends with concrete.

When specified in the contract documents, approved methods other than welding may be used for attaching steel grid floors (both open and concrete-filled types) to framing members. In such cases, welded headed shear connectors can be employed for concrete-filled grids and open steel grids can be connected to framing members by bolting.

14.7. Welding

All shop and field welding shall be done in accordance with the current edition of AASHTO/AWS D 1.5M/D 1.5 Bridge Welding Code.

Surfaces to be welded shall be free from paint, grease, loose scale, rust and other material that will prevent a proper weld. A thin coating of linseed oil, without pigment, need not be removed. Any clinkers or slag resulting from flame cutting or other causes shall be removed before welding.

14.8. Repairing Damaged Galvanized Coatings

Galvanized surfaces that are abraded or damaged at any time after the application of the zinc coating shall be repaired by thoroughly wire brushing the damaged areas and removing all loose and cracked coating, after which the cleaned areas shall be painted with two applications of unthinned, commercial quality zinc-rich primer (organic-vehicle type). Spray cans shall not be used.

14.9. Placement of Concrete Filler

14.9.1. Forms

Concrete-filled types of flooring with bottom flanges not in contact with each other shall be provided with bottom forms of metal or wood to retain the concrete filler without excessive leakage. Forms shall be removed after the concrete has been cured, except that metal forms conforming to the following paragraph may be left in place.

If metal form strips are used, they shall fit tightly on the bottom flanges or protrusions of the grid members and be placed in non-continuous lengths so as to extend not more than 25 mm onto the edge of each support, but in all cases the forms shall be such as will result in adequate bearing of slab on the support. If metal forms
are to be left in place, they shall either be galvanized or protective-treated by the same method that is required for the grid flooring.

14.9.2. Placement

When the contract documents indicate that the concrete filling does not extend to the bottom of the steel grid, the concrete, except concrete for cells in which shear connectors are to be installed, may be placed with the grid in an inverted position prior to installation, or the portion of the grid to remain unfilled may be blocked out by the use of a temporary inert filling material, such as sand or polystyrene board filler which is later removed, or by the use of metal lath form strips or other approved methods.

The method used shall permit full embedment of the tertiary bars and the shear connector studs, if used.

When the contract documents indicate that filled or partially filled grids or reinforced concrete slabs incorporating steel grids are to act compositely with their supporting members, all shear connecting studs shall be fully encased in concrete and the entire area between the top flange of the supporting member and the bottom of the grid filling shall be filled with concrete.

The concrete for filled grid floors shall be mixed, placed, and cured in accordance with the requirements of Section 10, "Concrete Structures." The concrete shall be thoroughly compacted by vibrating the steel grid floor. The vibrating device and the manner of operating it shall be subject to the approval of the Engineer.

14.10. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and this section requirements. For work acceptance, Contractor shall apply quality control for steel grid flooring work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.

14.10.1. Quality Control

The work should be controlled and inspected to insure that all this flooring materials as steel, concrete, in case of concrete-filled type are performed to meet the required quality measurements and steel was protected according to the articles 14.2.1, 14.2.2 and 14.2.3 and Table 14.3. Also, all materials used in grid flooring should be checked and insure that are fulfill the required specifications of article 14.2.4 for skid resistance.

For work acceptance sections arrangement and sections length should be controlled according to the article 14.3 and all installation and construction stages should be according to the specifications mentioned in articles 14.4, 14.5, 14.6, 14.7, 14.8 and 14.9.

14.10.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of steel grid flooring work, by reviewing the test reports and manufacturing certificates coming with the importing materials, and are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that insure the quality of all
sections that was finished according to the required tests mentioned in the related sections.

14.11. Measurement and Payment

Steel grid flooring shall be measured by the square meter. The number of square meters shall be based on the dimensions of the flooring in place and approved by the Engineer in the completed work.

Steel grid flooring shall be paid for at the contract document price per square meter. Such payment for steel grid floor, open, or concrete-filled types, shall be considered to be full compensation for the cost of furnishing of all materials, equipment, tools, and labor necessary for the satisfactory completion of the work.

Payment will be made as indicated in Table 14.1. And the quality control requirements for steel grid flooring are shown in Table 14.2.

Table 14.1: Steel Grid Flooring Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.2.1</td>
<td>Steel Grid flooring</td>
<td>Square Meter</td>
</tr>
</tbody>
</table>

Table 14.2: Quality Control Requirements For Steel Grid Flooring

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connection to Supports</td>
<td>Welds shall be spaced no greater than 400 mm on centers</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>---------</td>
<td>Article 14.6</td>
</tr>
<tr>
<td>Welding</td>
<td>Accordance with the current edition of AASHTO/AWS D 1.5M/D 1.5 Bridge Welding Code.</td>
<td>Assurance</td>
<td>In situ</td>
<td>---------</td>
<td>Article 14.7</td>
</tr>
</tbody>
</table>

Table 14.3: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
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<td>ASTM A 709/A 709M</td>
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<td>ASTM A 123/A 123M</td>
<td>Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products</td>
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14.12. References


SECTION 15. PAINTING

15.1. General

15.1.1. Description

This work shall consist of the painting of surfaces specified in the contract documents to be painted. The work shall be taken to include, but is not limited to, the preparation of surfaces to be painted; application and curing of the paint; protection of the work; protection of existing facilities, vehicles, and the public from damage due to this work; and the furnishing of all labor, equipment, and materials needed to perform the work.

15.1.2. Protection of Public and Property

The Contractor shall comply with all applicable environmental protection and occupational safety and health standards, rules, regulations, and orders. Failure to comply with these standards, rules, regulations, and orders shall be sufficient cause for suspension or disqualification.

All reasonable precautions shall be taken to contain waste materials (used blasting material and old paint) classified as hazardous. Disposal of hazardous waste material shall be performed in accordance with all applicable Federal, State, and Local laws.

The Contractor shall provide protective devices such as tarps, screens, or covers as necessary to prevent damage to the work and to other property or persons from all cleaning and painting operations. The Contractor shall be responsible for all damage caused by the painting project to vehicles, persons, or property.

Paint or paint stains that result in an unsightly appearance on surfaces not designated to be painted shall be removed or obliterated by the Contractor at the Contractor's expense.

15.1.3. Protection of the Work

The Contractor shall take all precautions necessary to protect the surface from contamination prior to or during the application process.

The Contractor shall protect all parts of the work against disfigurement by splatters, slashes, and smirches of paint materials.

All painted surfaces that are marred or damaged as a result of operations of the Contractor shall be repaired by the Contractor, at the Contractor's expense, with materials and to a condition equal to that of the coating specified herein.

If traffic causes an objectionable amount of dust, the Contractor, when directed by the Engineer, shall sprinkle the adjacent roadbed and shoulders with water or dust palliative for a sufficient distance on each side of the location where painting is being done.

Upon completion of all painting operations and of any other work that would cause dust, grease, or other foreign materials to be deposited on the painted surfaces, the painted surfaces shall be thoroughly cleaned. At the time of opening structures to public traffic, the painting shall be completed and the surfaces shall be undamaged and clean.
15.1.4. Thickness and Color

The dry film thickness of each coat and total thickness of the finished product shall be in accordance with the contract documents. The thickness of previously applied coatings or of an existing coating that is to be top coated shall be determined in accordance with SSPC-PA 2, Measurement of Dry Paint Thickness with Magnetic Gages, prior to applying the next coat.

Each coat of paint should be separately colored to ensure complete coverage, and such that the previous coat can be hidden by a single coat of the next application.

15.2. Painting Metal Structures

15.2.1. Coating Systems and Paints

The coating system and paints to be applied shall consist of the system in the contract documents.

15.2.2. Weather Conditions

Paint shall be applied only on thoroughly dry surfaces.

Painting shall not be permitted under any of the following circumstances:

- the atmospheric temperature, paint or the surface to be painted is at or below four degrees Celsius (4°C) or above thirty eight degree Celsius (38°C),
- metal surfaces are less than three degrees Celsius (3°C) above the dew point,
- the humidity exceeds eighty five percent (85%) at the site of the work,
- freshly painted surfaces may become damaged by rain, fog, or dust, or
- it can be anticipated that the atmospheric temperature will drop below five degrees Celsius (5°C) during the drying period, except as provided herein for painting in enclosures.

Metal surfaces which are hot enough to cause the paint to blister, to produce a porous paint film, or to cause the vehicle to separate from the pigment shall not be painted.

Subject to approval of the Engineer, the Contractor may provide a suitable enclosure to permit painting during inclement weather. Provisions shall be made to artificially control atmospheric conditions inside the enclosure within limits suitable for painting throughout the painting operation. Surfaces painted under cover in damp or cold weather shall remain under cover until the paint dries or weather conditions permit open exposure. Full compensation for providing and maintaining such enclosures shall be considered as included in the prices paid for the various contract items of work involving painting and, therefore, no additional compensation will be allowed.

All blast cleaning, except that performed with enclosed buildings, and all painting shall be performed during daylight hours unless otherwise specified in the contract documents.

15.2.3. Surface Preparation

All exposed surfaces of structural steel, except galvanized or metalized surfaces, shall be cleaned and painted.
All surfaces of new structural steel shall be cleaned by the blast-cleaning method unless otherwise specified in the contract documents or approved in writing by the Engineer.

In repainting existing steel structures, the method of cleaning shall be as specified in the contract documents. Any damage to sound paint, on areas not designated for treatment, resulting from the Contractor's operations shall be repaired by the Contractor at the Contractor's expense to the satisfaction of the Engineer.

The methods used in the cleaning of metal surfaces shall conform to the specifications herein.

15.2.3.1. Blast Cleaning

Abrasives used for blast cleaning shall be either clean dry sand, mineral grit, steel shot, or steel grit, at the option of the Contractor, and shall have a suitable grading to produce satisfactory results. The use of other abrasives shall not be permitted unless approved in writing by the Engineer.

Unwashed beach sand containing salt or excessive amounts of silt will not be allowed.

All dirt, mill scale, rust, paint, and other foreign material shall be removed from exposed steel surfaces in accordance with the requirements of the Steel Structures Painting Council Surface Preparation Specification No. 10, SSPC-SP 10, Near-White Blast Cleaning. Blast cleaning shall leave all surfaces with a dense and uniform anchor pattern of not less than 25.4 µm or more than 76.2 µm as measured with an approved surface profile comparator.

When blast cleaning is being performed near machinery, all journals, bearings, motors, and moving parts shall be sealed against entry of abrasive dust before blast cleaning begins.

Blast-cleaned surfaces shall be primed or treated the same day blast cleaning is done, unless otherwise authorized by the Engineer. If cleaned surfaces rust or are contaminated with foreign material before painting is accomplished, they shall be re-blast-cleaned by the contractor at the contractor's expense.

15.2.3.2. Steam Cleaning

All dirt, grease, loose chalky paint, or other foreign material that has accumulated on the previously painted or galvanized surfaces shall be removed with a steam cleaning apparatus which shall precede all other phases of cleaning. It is not intended that sound paint be removed by this process. Any paint which becomes loose, curled, lifted, or loses its bond with the preceding coat or coats after steam cleaning shall be removed as directed by the Engineer to sound paint or metal surface by the Contractor at the Contractor's expense.

A biodegradable detergent shall be added to the feed water of the steam generator or applied to the surface to be cleaned. The detergent shall be of such composition and shall be added or applied in such quantity that the cleaning as described in the above paragraph is accomplished.

Any residue, detergent, or other foreign material that may accumulate on cleaned surfaces shall be removed by flushing with fresh water.

Steam cleaning shall not be performed more than two weeks prior to painting or other phases of cleaning.
Subsequent painting shall not be performed until the cleaned surfaces are thoroughly dry and in no case in less than 24 h after cleaning and flushing.

15.2.3.3. Solvent Cleaning

Unless otherwise prohibited by the contract documents, solvents shall be used to remove oil, grease, and other soluble contaminants in accordance with the requirements of SSPC-SP 1, Solvent Cleaning. Solvent cleaning shall be performed prior to blast cleaning. If contamination remains after blasting, the area shall be recleaned with solvent.

15.2.3.4. Hand Cleaning

Wire brushes, either hand or powered, hand scraping tools, power grinders, or sandpaper shall be used to remove all dirt, loose rust and mill scale, or paint which is not firmly bonded to the metal surfaces.

Pneumatic chipping hammers shall not be used unless authorized in writing by the Engineer.

15.2.3.5. Power Washing

Power washing shall utilize water at a pressure between 5.5 MPa to 10.3 MPa, applied with the nozzle no further than 300 mm from the surface of the steel.

15.2.4. Application of Paints

The Contractor shall notify the Engineer, in writing, at least one week in advance of the date that cleaning and painting operations are to begin.

Painting shall be done in a neat manner. Unless otherwise specified in the contract documents, paint shall be applied by brush, spray, or roller, or any combination thereof peculiar to the paint being applied.

Each application of paint shall be thoroughly cured and any skips, holidays, thin areas, or other deficiencies corrected before the succeeding application. The surface of the paint being covered shall be free from moisture, dust, grease, or any other deleterious materials that would prevent the bond of the succeeding applications. In spot painting, old paint which lifts after the first application shall be removed by scraping and the area repainted before the next application.

Paints that are specified "formulated ready for application" and "no thinning" shall be allowed unless otherwise provided in the applicable materials specification for the paint being used.

Brushes, when used, shall have sufficient body and length of bristle to spread the paint in a uniform film. Round, oval-shaped brushes, or flat brushes not wider than 115 mm shall be used. Paint shall be evenly spread and thoroughly brushed out.

On all surfaces that are inaccessible for painting by regular means, the paint shall be applied by sheepskin daubers, bottle brushes, or by any other means approved by the Engineer.

Rollers, when used, shall be of a type that do not leave a stippled texture in the paint film. Rollers shall be used only on flat, even surfaces to produce a paint film of even thickness with no skips, runs, sags, or thin areas.

Paint may be applied with airless or conventional spray equipment.

Suitable traps or separators acceptable to the Engineer shall be furnished and installed in the airline to each spray pot to exclude oil and water from the air.
Any spray method which produces excessive paint build-up, runs, sags, or thin areas in the paint film, or skips and holidays, shall be considered unsatisfactory and the Engineer may require modification of the spray method or prohibit its use and require brushing instead.

Mechanical mixers shall be used to mix paint. Prior to application, paint shall be mixed a sufficient length of time to thoroughly mix the pigment and vehicle together, and shall be kept thoroughly mixed during its application.

The dry film thickness of the paint shall be measured in place with a calibrated magnetic film thickness gage according to Steel Structures Painting Council SSPC-PA2.

The thickness of each application shall be limited to that which will result in uniform drying throughout the paint film.

Succeeding applications of paint shall be of such shade as to contrast with the paint being covered.

Structures shall be blast-cleaned and painted with the total thickness of undercoats before erection. After erection and before applying subsequent paint, all areas where paint has been damaged or has deteriorated and all exposed unpainted surfaces shall be thoroughly cleaned and spot painted with the specified undercoats to the specified thickness.

Surfaces exposed to the atmosphere and that would be inaccessible for painting after erection shall be painted the full number of applications prior to erection.

Vinyl wash primer, if required, shall not be applied more than 12 h before application of the succeeding coat of paint. The vinyl wash primer shall be applied by spraying to produce a uniform wet film on the surface. The dry film thickness shall be between 7.6 and 12.7 µm.

The painting of areas under joint connection and splice plates shall conform to Article 13.5.6.3, "Surface Conditions".

15.2.4.1. Application of Zinc-Rich Primers

Zinc-rich primers, which include organic and inorganic zinc primers, shall be applied by spray methods. On areas inaccessible to spray application, the paint may be applied by brush or daubers.

Mechanical mixers shall be used in mixing the primer.

After mixing, zinc-rich primers shall be strained through a metal No. 30 to No. 60 250 to 600 µm mesh screen or a double layer of cheesecloth immediately prior to or during pouring into the spray pot.

An agitating spray pot shall be used in all spray application of zinc-rich primers. The agitator or stirring rod shall reach to within 50 mm of the bottom of the spray pot and shall be in motion at all times during primer application. Such motion shall be sufficient to keep the primer well mixed.

Spray equipment shall provide the proper pot pressure and atomization pressure to produce a coating, the composition of which shall comply in all respects to the specifications for zinc paint. The hose from pot to nozzle in the contract documents shall not be more than 22.5m long, nor be used more than 4.5m above or below the pot.

Cured, zinc-rich primer shall be free from dust, dirt, salt, or other deleterious deposits and thoroughly dry before applying vinyl wash primer.
Dry film thickness shall be measured in accordance with the Steel Structures Painting Council, SSPC-PA 2, August 1991.

In addition, the application of inorganic zinc paints shall conform to the following:

- Succeeding applications of inorganic zinc paints shall be applied within 24 h, but not less than 30 min after prior application of such paint.
- In areas where mud-cracking occurs in the inorganic zinc paint, it shall be blast-cleaned back to soundly bonded paint and recoated to the same thickness by the same methods specified for the original coat.
- Paint shall be cured for 48 h at a relative humidity of at least forty five percent (45%) before the application of vinyl wash primer. The cured inorganic zinc paint shall be hosed down with water and be in a surface dry condition before the application of vinyl wash primer if the vinyl wash primer is not applied within three weeks after the inorganic zinc paint is applied, or if there is evidence of dust, dirt, salt, or other deleterious deposits on the inorganic zinc paint.

15.2.5. Measurement and Payment

Cleaning and painting structural steel will be paid for on the basis of lump-sum prices, unless otherwise specified in the contract documents.

The lump-sum prices paid for clean structural steel and for paint structural steel or the lump-sum price paid for clean and paint structural steel shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in cleaning and painting structural steel as specified in the contract documents, these Specifications, and as directed by the Engineer.

15.3. Painting Galvanized Surfaces

All galvanized surfaces that are to be painted shall first be cleaned by washing with mineral spirit solvent sufficient to remove any oil, grease, or other materials foreign to the galvanized coating.

After cleaning, vinyl wash primer shall be applied to such surfaces. The vinyl wash primer shall be applied by spraying to produce a uniform wet film on the surface. The dry film thickness shall be between 7.6 and 12.7 μm.

Finish paint to be applied to primed galvanized surfaces shall be specified in the contract documents. If not otherwise specified, the finish paint shall be the same as that used on adjacent metal work or shall be as directed by the Engineer.

No separate payment shall be made for preparing and painting galvanized surfaces. Full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in preparing and painting galvanized surfaces as specified in the contract documents, these Specifications, and as directed by the Engineer will be considered as included in the prices paid for the various contract items of work involving the galvanized surfaces.

15.4. Painting Timber

15.4.1. General

Unless otherwise specified in the contract documents, all new timber requiring painting shall be painted with three applications of paint. The paint used for various
applications will be as specified in these Specifications or as specified in the contract documents.

The painting of previously painted surfaces shall be as required by the contract documents and Specifications herein.

15.4.2. Preparation of Surfaces
All cracked or peeled paint, loose chalky paint, dirt, and other foreign material shall be removed by wire brushing, scraping, or other means immediately prior to painting. The moisture content of the timber shall not be more than twenty percent (20%) at the time of the first application.

15.4.3. Paint
Paint for timber structures, except as otherwise provided herein, shall be as specified in the contract documents. The paint as specified is intended for use in covering previously painted surfaces. When it is applied to unpainted timber, turpentine and linseed oil shall be added as required by the character of the surface in an amount not to exceed one-eighth of the paint as specified. The paint shall be either white or tinted as directed by the Engineer.

If a black finish paint is specified in the contract documents, the first or prime coat shall be as specified above.

15.4.4. Application
When permitted in writing by the Engineer, the first application of paint may be applied prior to erection.

After the first application has dried and the timber is in place, all cracks, checks, nail holes, or other depressions shall be puttied flush with the surface and allowed to dry before the second application of paint.

Paint shall be applied by brush, air spray, or roller; spread evenly; and worked thoroughly into all seasoning cracks, corners, and recesses. No later coat shall be applied until the full thickness of the previous coat has dried.

Final brush strokes with aluminum paint shall be made in the same direction to ensure that powder particles "leaf" evenly.

15.4.5. Painting Treated Timber
Timber treated with creosote or oil-borne pentachlorophenol preservatives shall not be painted.

Timber treated with water-borne preservatives shall be clean and be reduced to no more than twenty percent (20%) moisture content before it is painted. Any visible salt crystals on the wood surface shall be washed and brushed away, and the moisture content reduced again to the specified level before painting. Stored timber awaiting painting shall be covered and stacked with spreaders to ensure air circulation.

15.4.6. Payment
No separate payment shall be made for preparing surfaces and for painting new timber. The painting of existing timber shall be paid for on the basis of lump-sum prices. Full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in preparing surfaces and painting timber, as specified in these Specifications and the contract documents, and as directed
by the Engineer shall be considered as included in the prices paid for the various contract items of work involving new timber or the prices paid for painting existing timber.

15.5. Painting Concrete

15.5.1. Surface Preparation

Prior to painting concrete surfaces, laitance and curing compounds shall be removed from the surface by abrasive blast cleaning in accordance with Article [15.2.3.1] "Blast Cleaning."

Concrete surfaces shall be thoroughly dry and free of dust at the time the paint is to be applied.

Any artificial drying procedures and methods shall be subject to approval by the Engineer.

15.5.2. Paint

Unless otherwise specified in the contract documents, paint to be applied to concrete surfaces shall be acrylic emulsion and shall comply in all respects to the following Master Painters Institute Detailed Performance Standards:

- MPI –# 10 for flat paint,  
- MPI –# 11 for semi-gloss,  
- MPI –#119 for gloss.

- MPI –#10 Flat (Gloss Level) 0-5 units
- MPI –#11 Semi-Gloss (Gloss Level 5) 35-70 units
- MPI –#119 Gloss (Gloss Level 6) 70-85 units

This paint may be tinted by using "universal" or "all purpose" concentrates.

15.5.3. Application

Acrylic emulsion paint shall be applied in not less than two applications to produce a uniform appearance.

The paint shall be applied only when the ambient temperature is ten degrees Celsius (10°C) or above. Painting shall not be permitted when it can be anticipated that the ambient temperature will drop below ten degrees Celsius (10°C) during the application and drying of the paint.

15.6. Works Acceptance

All materials and works should be controlled according to the requirements of the article [3.6] "control and acceptance of materials and work", and this section requirements. For work acceptance, Contractor shall apply quality control for painting work through carrying out all the required procedures to insure that used painting materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.

15.6.1. Quality Control

The painting work should be controlled and inspected to insure that all painting works according to the surface types are performed to meet the required quality measurements and inspection of surface preparation before the work and the correction method of the surface cleaning work were choices by the contractor according to the
Table 15.2 shows the tests required for quality control measurements and sampling instructions. For more specifications of painting materials are available in Table 15.3.

### 15.6.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of painting work, by reviewing the manufacturing certificates coming with the importing materials and the surface preparation works, and are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that insure the quality of all works that was finished according to the required tests mentioned in the related sections.

### 15.7. Measurement and Payment

Preparing and painting concrete will be measured either by the lump sum or by the square meter as listed in the contract documents. When measured by the square foot square meter, measurement will be determined along the surface of the actual area painted.

The contract price paid per lump sum or square meter to prepare and paint concrete shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in preparing the concrete and applying the paint to concrete surfaces, as specified in these specifications and the contract documents, and as directed by the Engineer.

Payment will be made under one or more of the items in Table 15.1. And quality control requirements for painting are shown in Table 15.2.

#### Table 15.1: Painting Pay Items

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<td>Lump Sum</td>
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<td>15.3</td>
<td>Painting Galvanized Surfaces</td>
<td>Lump Sum</td>
</tr>
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<td>15.4</td>
<td>Painting Timber</td>
<td>Lump Sum</td>
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<td>15.5</td>
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<td>Square Meter</td>
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#### Table 15.2: Quality Control Requirements For Painting

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<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
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<td>Existing Steel Structures</td>
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<td>In situ</td>
<td>Article 15.2, 15.3</td>
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<td>Cleaning shall be as specified in the contract documents</td>
<td>Surveying</td>
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<td>Article 15.2, 15.5</td>
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<td>Concrete surfaces</td>
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<tr>
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<td>Shall be thoroughly dry and free of dust</td>
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### Section 15: Painting

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#### 15.8. References


SECTION 16. BEARING DEVICES

16.1. General
This work shall consist of furnishing and installing bridge bearings and the bedding of materials used under masonry plates.

Bearings shall be constructed in accordance with the details shown in the contract documents. When complete details are not provided, bearings shall be furnished that conform to the limited details shown in the contract documents and shall provide the design capacities for loads and movements shown or specified and the performance characteristics specified.

16.2. Working Drawings
The Contractor shall prepare and submit working drawings for the bearings. Such drawings shall show all details of the bearings and of the materials proposed for use and shall be approved by the Engineer prior to the fabrication of the bearings. Such approval shall not relieve the Contractor of any responsibility under the contract documents for the successful completion of the work.

The following shall be specified on the working drawings:
• The total quantity of each kind of bearing required (fixed, guided expansion, or non-guided expansion), grouped first according to type (load range), and then by actual design capacity.
• The plan view and section elevation view showing all relative dimensions of each type of bearing.
• The maximum design coefficient of friction as noted in the contract documents.
• The type of materials to be used for all bearing elements.
• If applicable, a clear description and details for any welding process used in the bearing manufacture that does not conform to the approved processes of the current AASHTO/AWS D1.5M/D1.5 Bridge Welding Code.
• The vertical and horizontal load, rotation, and movement capacity.
• Painting or coating requirements.
• Alignment plans.
• Installation scheme.
• Complete design calculations verifying conformance with these Specifications, if required by the Engineer.
• Anchorage details.
• Bearing preset details, if applicable.
16.3. Materials

16.3.1. General

16.3.1.1. Rolled Steel
Rolled steel shall be of the type specified in the contract documents and shall satisfy the testing requirements of the standard to which it conforms. Unless otherwise specified, steel shall conform to AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grade 250, and shall cause no adverse electrolytic or chemical reaction with other components of the bearing and shall be free of all rust and mill scale.

16.3.1.2. Steel Laminates
Unless otherwise specified in the contract documents, steel laminates used for reinforcement shall be made from rolled mild steel conforming to AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grade 250, ASTM A 1011/A 1011M, or equivalent. Laminates shall have a minimum nominal thickness of 1.6 mm. Holes in plates for manufacturing purposes shall not be permitted unless they have been accounted for in the design and are in accordance with the contract documents.

16.3.1.3. Cast Steel
Cast steel shall satisfy the requirements of ASTM A 802/A 802M and be free of all blow-holes and impurities larger than 3.2 mm. The inside wall of the pot in pot bearings and the contact surface of metal rocker or roller bearings shall be free of blow holes or impurities of any size.

16.3.1.4. Forged Steel
Forged steel shall satisfy the requirements of ASTM A 788.

16.3.1.5. Stainless Steel
Stainless steel shall conform to the requirements of ASTM A 167, Type 304 or ASTM A 240/A 240M, Type 304 and shall have a minimum thickness of 0.91 mm and a surface finish in the finished bearing better than or equal to 0.2 µm. Stainless steel in contact with polytetrafluoroethylene (PTFE) sheet shall be polished to a finish no less than 0.50 µm.

16.3.2. Special Material Requirements for Electromagnetic bearings

16.3.2.1. Properties of the Elastomer
The raw elastomer shall be either virgin Neoprene (polychloroprene) or virgin natural rubber (polysoprene). The elastomer compound shall be classified as being of low-temperature Grade 0, 2, 3, 4, or 5. The grades are defined by the testing requirements in Table 16.1 and Table 16.2. A higher grade of elastomer may be substituted for a lower one.

The elastomer compound shall meet the minimum requirements of Table 16.1 and Table 16.2 except as otherwise specified by the Engineer. Test requirements may be interpolated for intermediate hardness. If the material is specified by its shear modulus, its measured shear modulus shall lie within fifteen percent (15%) of the specified value. A consistent value of hardness shall also be supplied for the purpose of defining limits for the tests in Table 16.1 and Table 16.2. If the hardness is specified, the measured
shear modulus must fall within the range of Table 12.5 of the (MA-100-D-V2/2). When test specimens are cut from the finished product, the physical properties shall be permitted to vary from those specified in Table 16.1 and Table 16.2 by ten percent (10%). All material tests shall be carried out at twenty-three degree Celsius plus or minus two degree Celsius (23°C±2°C), unless otherwise noted. Shear modulus tests shall be carried out using the apparatus and procedure described in Annex A of ASTM D 4014.

Table 16.1: Polychloroprene (Neoprene) Quality-Control Tests

<table>
<thead>
<tr>
<th>ASTM Test Method</th>
<th>Physical Properties</th>
<th>D 2240</th>
<th>D 412</th>
<th>D 573, 70 h at 100°C</th>
<th>D 1149</th>
<th>D 412</th>
<th>D 412</th>
<th>D 412</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shear modulus</td>
<td>50±5</td>
<td>60±5</td>
<td>70±5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tensile Strength, minimum</td>
<td>15.5</td>
<td>15.5</td>
<td>15.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ultimate Elongation, minimum %</td>
<td>400</td>
<td>350</td>
<td>300</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Heat Resistance</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change in Durometer Hardness, maximum points</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change in Tensile Strength, maximum %</td>
<td>-15</td>
<td>-15</td>
<td>-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change in Ultimate Elongation, maximum %</td>
<td>-40</td>
<td>-40</td>
<td>-40</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Compression Set</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>22 h at 100°C, maximum %</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td></td>
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<tr>
<td></td>
<td>Ozone</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>100 ppm Ozone in Air by Volume, 20% Strain 38°C ± 1°C</td>
<td>No Cracks</td>
<td>No Cracks</td>
<td>No Cracks</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Procedure D 518 Procedure A</td>
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</tr>
<tr>
<td></td>
<td>Low-Temperature Brittleness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grades 0 and 2-No Test Required</td>
<td>No Failure</td>
<td>No Failure</td>
<td>No Failure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grade 3-Brittleness at -40°C</td>
<td>No Failure</td>
<td>No Failure</td>
<td>No Failure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grade 4-Brittleness at -48°C</td>
<td>No Failure</td>
<td>No Failure</td>
<td>No Failure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grade 5-Brittleness at -56.5°C</td>
<td>No Failure</td>
<td>No Failure</td>
<td>No Failure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Instantaneous Thermal Stiffening</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grades 0 and 2- Tested at -32°C</td>
<td>Stiffness at test temperature shall not exceed four times the stiffness measured at 23°C</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Grade 3- Tested at – 40°C</td>
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<tr>
<td></td>
<td>Grade 4- Tested at -45.5°C</td>
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<tr>
<td></td>
<td>Grade 5- Tested at -34°C</td>
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<tr>
<td></td>
<td>Low-Temperature Crystallization</td>
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<tr>
<td></td>
<td>Grade 0-No Test required</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Grade 2-7 days at -18°C</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grade 3-14 days at -26°C</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Grade 4-21 days at -37°C</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>Grade 5-28 days at -37°C</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
### Table 16.2: Polyisoprene (Natural Rubber) Quality-Control Tests

<table>
<thead>
<tr>
<th>ASTM Test Method</th>
<th>Physical Properties</th>
<th>D 2240</th>
<th>D 412</th>
<th>D 573, 70 h at 70°C</th>
<th>D 412</th>
<th>D 573, 70 h at 70°C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hardness (Shore A Durometer)</td>
<td>50±5</td>
<td>60±5</td>
<td>70±5</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Tensile Strength, minimum MPa</td>
<td>15.5</td>
<td>15.5</td>
<td>15.5</td>
<td>-25</td>
<td>-25</td>
</tr>
<tr>
<td></td>
<td>Ultimate Elongation, minimum %</td>
<td>450</td>
<td>400</td>
<td>300</td>
<td>-25</td>
<td>-25</td>
</tr>
<tr>
<td></td>
<td>Heat Resistance</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>Change in Durometer Hardness, maximum points</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Change in Tensile Strength, maximum %</td>
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<tr>
<td></td>
<td>Change in Ultimate Elongation, maximum %</td>
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<tr>
<td></td>
<td>Compression Set</td>
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<td></td>
<td>Change in Tensile Strength, maximum %</td>
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<tr>
<td></td>
<td>Change in Ultimate Elongation, maximum %</td>
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<td></td>
<td>Ozone</td>
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<tr>
<td></td>
<td>Change in Tensile Strength, maximum %</td>
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<tr>
<td></td>
<td>Change in Ultimate Elongation, maximum %</td>
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<td></td>
<td>Ozone</td>
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<tr>
<td></td>
<td>Change in Tensile Strength, maximum %</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Change in Ultimate Elongation, maximum %</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Instantaneous Thermal Stiffening</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Change in Tensile Strength, maximum %</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Change in Ultimate Elongation, maximum %</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Low-Temperature Brittleness</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Change in Tensile Strength, maximum %</td>
<td></td>
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<tr>
<td></td>
<td>Change in Ultimate Elongation, maximum %</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Low-Temperature Crystallization</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Change in Tensile Strength, maximum %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change in Ultimate Elongation, maximum %</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Materials**

Stiffness at test temperature shall not exceed four times the stiffness measured at 23°C.

Stiffness at test time and temperature shall not exceed four times the stiffness measured at 23°C with no time delay. The stiffness shall be measured with a quad shear test rig in an enclosed freezer unit. The test specimens shall be taken from a randomly selected bearing. A ±25% strain cycle shall be used and a complete cycle of strain shall be applied with a period of 100 s. The first 0.75 cycle of strain shall be discarded and the stiffness shall be determined by the slope of the force deflection curve for the next 0.25 cycle of loading.
16.3.2.2. Fabric Reinforcement

Fabric reinforcement shall be woven from hundred percent one hundred percent (100%) continuous glass fibers of "E" type yarn. The minimum thread count in either direction shall be one thread per mm. The fabric shall have either a crowfoot or an 8 hardness satin weave. Each ply of fabric shall have a minimum breaking strength of 140 N/mm of width in each thread direction. Unless otherwise specified in the contract documents, holes shall not be permitted in the fabric.

16.3.2.3. Bond

The vulcanized bond between fabric and reinforcement shall have a minimum peel strength of 5.3 N/mm. Steel laminated bearings shall develop minimum peel strength of 7.0 N/mm. Peel strength tests shall be performed by ASTM D 429, Method B.

16.3.3. Special Material Requirements for Pot and desk Bearing

All materials shall be new and unused, with no reclaimed material incorporated in the finished bearing.

16.3.3.1. Steel

All steel except stainless steel components of the pot and disc bearing shall conform to the requirements of Article 13.3, "Materials" in Section 13, "Steel Structures", for carbon steel or high-strength, low-alloy structural steel for welding.

16.3.3.2. Stainless Steel

Stainless steel shall conform to the requirements of Article 16.3.1.5, "Stainless Steel".

16.3.3.3. Elastomeric Rotational Element For Pot Bearings

The elastomeric rotational element used in the construction of pot bearings shall contain only virgin, crystallization-resistant polychloroprene (Neoprene), AASHTO M251 (ASTM D4014) or virgin natural polyisoprene (natural rubber), AASHTO M251 as the raw polymer. The physical properties of Neoprene and natural rubber shall conform to the Specifications above with modifications as follows:

- The Shore A Durometer hardness shall be 50±10 points.
- Samples for compression set tests shall be prepared using a Type 2 die.

16.3.3.4. Sealant for Pot Bearings

The elastomer shall be lubricated between the steel pot and the top steel bearing plate with a silicon grease which does not react chemically with the elastomer and does not alter its properties within the range of environmental conditions expected at the site or as recommended by the Manufacturer.

---

1 E-glass Fiber Yarn: High strength, electrical insulation. It is widely used as an electrical insulation material.
16.3.3.5. Sealing Rings For Pot Bearings

The sealing rings between the steel piston and the elastomeric rotational element of pot bearings shall be made of brass conforming to ASTM B 36/B 36M for rings of rectangular cross-section and ASTM B 121/8 121M for circular sections. The Engineer, at the Engineer's discretion, may approve other sealing ring material on the basis of test evidence conforming to Article 12.6.6.4.5 of the (MA-100-D-V2/2).

16.3.3.6. Polytetrafluorethylene (PTFE) Sheet and Strip

PTFE sheet and strip requirements for pot and disc bearings shall conform to the provisions of Article [16.7.7.1]. "General".

16.3.3.7. Polyether Urethane Structural Element for Disc Bearings

The polyether urethane structural element used in the construction of disc bearings shall be molded from a monolithic polyether urethane compound. The physical properties of the polyether urethane shall conform to the requirements listed in Table [16.3] below.

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>ASTM Test Method</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness, Type D Durometer</td>
<td>D2240</td>
<td>45 55 65</td>
</tr>
<tr>
<td>Tensile Stress, MPa</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At 100% elongation</td>
<td>D412</td>
<td>10 13 16</td>
</tr>
<tr>
<td>At 200% elongation</td>
<td></td>
<td>19 23 28</td>
</tr>
<tr>
<td>Tensile Strength, MPa</td>
<td>D412</td>
<td>28 35 41</td>
</tr>
<tr>
<td>Ultimate Elongation, %</td>
<td>D412</td>
<td>350 285 220</td>
</tr>
<tr>
<td>Compression Set, 22 h at 70°C, %</td>
<td>D395</td>
<td>40 40 40</td>
</tr>
</tbody>
</table>

16.3.4. Special Material Requirements for Rocker and Roller Bearings

Steels used in rocker and roller bearings shall be of the types and grades as specified in the contract documents. The steel at the contact surface of a metal bearing may be hardened provided that, after hardening, the steel satisfies the strength and ductility requirements of the contract documents and the material specifications.

16.3.5. Metal Plates Used in Masonry, Sole and Shim Plates

Metal plates used in masonry, sole, and shim plates, unless otherwise specified in the contract documents, shall conform to AASHTO M 270M/M 270 (ASTM A 709/A 709M) Grade 250. Bronze or copper alloy bearing and expansion plates shall conform to the requirements of Article [16.7.5]. "Bronze or Copper-Alloyed Plates for Bearings".
16.3.6. Special Material Requirements for PTFE Sliding Surfaces

16.3.6.1. PTFE Sheet and Strip

PTFE resin sheets, PTFE fabric, interlocked bronze and PTFE structures, PTFE-perforated metal composite, back-up materials, and all other parts of fixed or expansion bearings containing PTFE materials shall have the friction, mechanical, physical, and weathering properties specified in the contract documents.

16.3.6.2. PTFE Resin

PTFE resin shall be one hundred percent (100%) pure, new material meeting the requirements of ASTM D 4894 or D 4895. It shall satisfy the requirements of Table 16.4. No reclaimed material shall be used.

Finished PTFE sheet, strip, and fabric shall be:
- resistant to acids, alkalis, and petroleum products,
- stable at temperatures from minus two hundred and eighteen degree Celsius to two hundred and sixty degree Celsius (-218°C to 260°C),
- nonflammable, and
- non-absorbing of water.

16.3.6.3. Filler Material

Filler material, when used, shall be milled glass fiber, carbon fiber, or other approved filler material. The filler shall act compositely with PTFE and shall not have any chemical reaction with other components or constituents.

16.3.6.4. Adhesive Material

Adhesive material used for bonding sheet PTFE shall be an epoxy resin satisfying the requirements of AASHTO M 235M/M 235 (ASTM C 881/C 881M), FEP film or equal, as approved by the Engineer.

16.3.6.5. Unfilled PTFE Sheet

Finished, unfilled PTFE sheet shall be made from virgin PTFE resin and shall conform to Table 16.4 with the exception that the ASTM test methods for tensile strength and elongation shall conform to ASTM D 2256.

16.3.6.6. Filled PTFE Sheet

Filled PTFE sheet shall be made from virgin PTFE resin uniformly blended with approved inert filler. The maximum filler content shall be fifteen percent (15%) for fiberglass and twenty-five percent (25%) for carbon fibers. The maximum filler content for other materials shall be determined by the Engineer.

Finished filled PTFE sheets containing glass fiber or carbon shall conform to the following requirements of Table 16.4 with the exception that the ASTM test methods for tensile strength and elongation shall conform to ASTM D 638.
Table 16.4: Filled PTFE Sheet

<table>
<thead>
<tr>
<th>Mechanical Property</th>
<th>ASTM Method</th>
<th>Sheet Unfilled</th>
<th>Sheet with 15% Glass Fibers</th>
<th>Sheet with 25% Carbon Fibers</th>
<th>Woven Fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength min. MPa</td>
<td>D 638 or D 2256</td>
<td>19.3</td>
<td>13.78</td>
<td>8.96</td>
<td>16.54</td>
</tr>
<tr>
<td>Elongation min. %</td>
<td>D 638 or D 2256</td>
<td>200</td>
<td>150</td>
<td>75</td>
<td>35</td>
</tr>
<tr>
<td>Specific Gravity, min.</td>
<td>D 792</td>
<td>623 ± 2</td>
<td>2.20 ± 0.03</td>
<td>2.10 ± 0.03</td>
<td>-</td>
</tr>
<tr>
<td>Melting Point, °C</td>
<td>D 4894, D 4895 or D 5977</td>
<td>328 ± 2</td>
<td>328 ± 10</td>
<td>328 ± 10</td>
<td>-</td>
</tr>
</tbody>
</table>

Values for intermediate filler contents may be obtained by interpolation.

16.3.6.7. Fabric Containing PTFE Fibers

Woven Fabric PTFE shall be manufactured from oriented multi-filament PTFE fluorocarbon fibers or from a mixture of PTFE fibers made from twisted, slit PTFE tape and other fibers as required by proprietary designs. Typical physical properties of the PTFE fibers shall be taken from Table 16.4 with the exception that the ASTM Test Methods for tensile strength and elongation shall conform to ASTM D 2256.

16.3.6.8. Lubricants

Lubricants, if used, shall consist of a combination of solids which does not react chemically or electrolytically with the PTFE and its mating surface and shall remain stable in the environmental conditions expected at the bridge site.

16.3.6.9. Interlocked Bronze and Filled PTFE Structures

Interlocking bronze and filled PTFE structures shall consist of a phosphor bronze plate with a 0.25 mm thick porous bronze surface layer into which is impregnated a lead/PTFE compound. There shall be an overlay of compounded PTFE not less than 25 mm thick. The phosphor bronze back plate shall conform to AASHTO M 108 (ASTM B 100) and the porous bronze layer shall conform to ASTM B 103/B 103M.

16.3.6.10. Surface Treatment

Where PTFE sheets are to be epoxy-bonded, one side of the PTFE sheet shall be factory-treated by an approved Manufacturer by the sodium naphthalene or sodium ammonia process.

16.3.6.11. Stainless Steel Mating Surface

Stainless steel shall conform to the requirements of Article 16.3.5. "Stainless Steel".

16.3.7. Special Requirements for Anchor Bolts

Anchor bolts shall meet the requirements of ASTM A 307, or as shown in the contract documents. Anchor bolts shall be provided with anchorage details that permit development of the full tensile strength of the bolt. Hooks or end plates are recommended.
16.3.8. Special Material Requirements for Bedding of Masonry Plates

Filler or fabric materials shall be placed as bedding material under masonry plates when shown in the contract documents. Such material shall be of the type specified in the contract documents or as ordered or approved by the Engineer and shall be installed to provide full bearing on contact areas.

Immediately before placing the bedding material and installing bearings or masonry plates, the contact surfaces of the concrete and steel shall be thoroughly cleaned.

Preformed fabric pads used as bedding shall be composed of multiple layers of 2.7 N/m² cotton duck impregnated and bonded with high-quality natural rubber or of equivalent and equally suitable materials compressed into resilient pads of uniform thickness. The number of plies shall be such as to produce the specified thickness, after compression and vulcanizing. The finished pads shall withstand compression loads perpendicular to the plane of the laminations of not less than 70 MPa without detrimental reduction in thickness or extrusion.

Sheet lead used as bedding shall be common, desilverized lead conforming to ASTM B 29. The sheets shall be of uniform thickness and shall be free from cracks, seams, slivers, scale, and other defects. Unless otherwise specified, lead sheets shall be 3 mm in thickness with a permissible tolerance of ±1 mm.

Caulking material used as bedding shall be a non-sag polysulfide or polyurethane material conforming to the provisions of ASTM C 920, Type II.

Grout and mortar used for filling under masonry plates shall conform to Section 10 Article, "Mortar and Grout".

16.4. Fabrication

The Contractor shall provide the Engineer with written notification 30 days prior to the start of bearing fabrication.

The finish of the mold used to produce the elastomeric rotational element for pot bearings or the polyether urethane structural element for disc bearings shall conform to good machine shop practice.

PTFE sheet shall be bonded to a grit-blasted steel substrate using an epoxy resin adhesive under controlled factory conditions in accordance with the instructions of the adhesive Manufacturer. The PTFE sheet shall be recessed into its steel substrate for at least one-half of its thickness. If on a vertical surface, the PTFE sheet may be mechanically fastened to the substrate. The attachment of the PTFE sheet to its substrate shall be done in accordance with the manufacturing requirements of Article 16.3.6 "Special Material Requirements for PTFE Sliding Surfaces ".

After fabrication, steel surfaces exposed to the atmosphere, except stainless steel surfaces, shall be shop painted or coated to protect against corrosion as specified in the contract documents. Prior to coating, the exposed steel surfaces shall be cleaned in accordance with the recommendations of the coating manufacturer. Metal surfaces to be field-welded shall be given a coat of clear polish or other protective coating approved by the Engineer, if the time of exposure before welding takes place is to exceed three months. The lacquer coating shall be removed at the time of welding. The final painting or coating of these surfaces shall be done after the completion of welding.

Stainless steel sheet shall be attached to a steel substrate with an approved epoxy to ensure complete contact and then sealed with a continuous weld.
All welding shall conform to and all welders shall be qualified in accordance with the requirements of the current AASHTO/A WS D1.5M/D1.5 Bridge Welding Code.

Except as noted, all bearing surfaces of steel plates shall be finished or machined flat within 0.0008 mm/mm. Out-of-flatness greater than 0.0008 mm/mm on any plate shall be a cause for rejection. The bottom surfaces of lower bearing plates (masonry plates) designed to rest on bearing pads shall not exceed an out-of-flatness value of 0.005 mm/mm. Oxygen-cut surfaces shall not exceed a surface roughness value of 25 µm, as defined by ANSI B46.1.

Gross bearing dimensions shall have a tolerance in accordance with the Manufacturers Specifications.

Every bearing shall have the project identification number, lot number, and individual bearing number indelibly marked with ink on a side that will be visible after erection.

### 16.5. Testing and Acceptance

#### 16.5.1. General

Testing and acceptance criteria for bearings shall conform to the minimum requirements specified in Article 3378H, "Tests". The Engineer may impose more stringent standards.

The minimum frequency of testing for different bearing types is set out in Article 3379H, "Special Testing Requirements".

When bearings are manufactured from a number of components, each component shall satisfy the testing requirements from the applicable section.

The Engineer shall be given free access to inspect the manufacture of the bearings at all times.

#### 16.5.1.1. Definitions

- **Load Range** - is a range of load capacities in which the highest capacity is no more than 2.0 times as large as the lowest.

- **Lot** - is a group of no more than 25 bearings of the same type (e.g. elastomeric or pot bearings, and fixed, guided or floating), in the same load range.

- **Batch** - is a body of material in which the ingredients are uniformly blended together at one time.

- **Sample** - is a piece of material or a complete bearing which is tested in order to infer the properties of the batch of material or group of bearing elements from which it is taken. A sample shall consist of at least one bearing chosen randomly from each lot and material batch and shall comprise at least ten percent (10%) of the lot.

#### 16.5.1.2. Test pieces to be supplied to the Engineer

#### 16.5.1.3. Tapered Sole Plates

Each bearing with a tapered sole plate that is selected for testing shall be delivered to the test site accompanied by an unattached plate identical to the tapered sole plate. The single beveled plate shall be so constructed that, when placed in contact with the tapered sole plate, the two shall form a single body, rectangular in shape and uniform in thickness.
16.5.2. Tests

16.5.2.1. General
The tests specified herein shall be carried out at the Manufacturer's expense. Unless otherwise agreed by the Engineer, they shall be supervised by an independent and disinterested testing agency.

Additional tests for specific types of bearings, as specified in other articles of these Specifications, shall also be conducted.

16.5.2.2. Material Certification Tests
Material certification tests to determine the physical and chemical properties of all materials shall be conducted in accordance with the appropriate specification governing the material. The test certificates shall be provided to the Engineer.

16.5.2.3. Material Friction Test-Sliding Surfaces Only
The coefficient of friction between the two mating surfaces shall be measured. Tests shall be conducted on either on samples taken from the same batch of materials as those used in the prototype bearings shall be used or the tests may, at the Manufacturer's option, or conducted on finished bearings. Only new materials shall be used and no material that has been previously tested shall be used.

The surfaces shall be thoroughly cleaned with a degreasing solvent. No lubrication other than that specified for the prototype bearings shall be used. The mating surfaces for the test pieces shall have a common area no less than the smaller of the bearing area or 4500 mm$^2$.

The test pieces shall be loaded in compression to a stress corresponding to their maximum service dead load plus live load, which shall be held constant for 1 h prior to and throughout the duration of the sliding test. At least 100 cycles of sliding, each consisting of at least ±25 mm of movement, shall then be applied at a temperature of twenty degree Celsius plus or minus one degree Celsius ($20\pm1^\circ C$). The uniform sliding speed shall be 65 mm per min.

The breakaway friction coefficient shall be computed for each direction of each cycle and its mean and standard deviation shall be computed for the sixth through twelfth cycles. The initial static breakaway coefficient of friction for the first cycle shall not exceed twice the design coefficient of friction. The maximum coefficient of friction for all subsequent cycles shall not exceed the design coefficient of friction. Failure of a single sample shall result in rejection of the entire lot.

Following the 100 cycles of testing, the breakaway coefficient of friction shall be determined again and shall not exceed the initial value. The bearing or specimen shall show no appreciable sign of wear, bond failure, or other defects.

16.5.2.4. Dimension Check
The dimensions of the bearing shall be checked. Two types of dimensions, standard and critical, shall be measured. The values of the critical dimensions shall be recorded and provided by the Manufacturer to the Engineer. Failure of a critical dimension to satisfy its tolerance shall be a cause for rejection. Failure of a standard measurement to satisfy its tolerance shall, at the discretion of the Engineer, be a cause for rejection. Flatness shall be checked by placing a precision straightedge on the surface to be checked and by inserting feeler gauges between the two. The straightedge shall be
placed at different orientations and the worst condition shall be established. No more than three feeler gauges may be stacked on top of one another. The straightedge shall be as long as the largest dimension of the flat surface. Flatness shall satisfy the requirements of Manufacturers Specifications.

16.5.2.5. Clearance Test

The components of the bearing shall be moved through their design displacements or rotations to verify that the required clearances exist. If the test is conducted on a rotational component which is not under simultaneous full vertical load; allowance shall be made for the displacements which would be caused by that load.

16.5.2.6. Short-Term Compression Proof Load Test

The bearing shall be loaded in compression to one hundred and fifty percent (150%) of its rated service load. If a rotational element exists, a tapered plate shall be introduced in the load train so that the bearing sustains the load at the maximum simultaneous design rotation. The load shall be held for 5 minutes, removed, then reapplied for a second period of 5 minutes. The bearing shall be examined visually while under the second loading. Any defects shall constitute cause for rejection. If the load drops below the required value during either application, the test shall be restarted from the beginning.

16.5.2.7. Long-Term Compression Proof Load Test

The test shall be conducted in the same way as the short-term proof load test except that the second load shall be maintained for 15 hours. If the load drops below ninety percent (90%) of its target value during this time, the load shall be increased to the target value and the test duration shall be increased by the time for which the load was below the required value.

16.5.2.8. Bearing Friction Test (for sliding surfaces only)

The purpose of the Bearing Friction Test is to verify that the friction values achieved in the material friction tests are adequate predictors of the friction in the finished bearing.

No lubrication shall be applied except that used for the whole lot of bearings. The bearing shall be loaded in compression with one hundred percent (100%) of the full service dead plus live load, which shall be held constant for one hour prior to and throughout the duration of the sliding test. At least 12 cycles of sliding, each consisting of the smaller of the design displacement and ± 26 mm of movement, shall then be applied. The average sliding speed shall be 65 mm/minute. When the test is applied to curved sliding bearings, the design rotation shall be used in place of the displacement.

In flat sliding bearings, the breakaway friction coefficient shall be computed for each direction of each cycle, and its mean and standard deviation shall be computed for the sixth through twelfth cycles. Neither the friction coefficient for the first movement nor the mean plus two standard deviations for the sixth through twelfth cycles shall exceed the value used in design, and the mean value for the sixth through the twelfth cycles shall not exceed two third, of the value used in design.

In curved sliding surfaces, the moment corresponding to the design rotation shall be established at each peak movement (positive and negative) during the first and last six cycles of testing. The corresponding load eccentricity shall be calculated by dividing
the moment by the total compressive load acting. The eccentricity shall be small enough that the allowable stresses on the PTFE used in design are not violated.

16.5.2.9. Long-Term Deterioration Test
The test shall either be conducted on samples of the materials used in the bearings or at the option of the Manufacturer, it may be conducted on a pair of bearings, placed back-to-back. The samples shall have an area not less than 4500 mm$^2$. The test piece shall first be loaded in compression to a stress corresponding to hundred percent (100%) of the maximum dead load plus live service load. Flat sliding systems shall then be displaced through at least 1000 cycles with amplitude of at least ±25 mm (50 mm peak to peak.) Curved sliding systems and rotational systems that depend on deformation of an elastomeric element shall be subjected to 5000 cycles or displacements corresponding to a rotation of plus or minus the design amplitude. The sliding may take place at up to 250 mm per min, except when readings of the coefficient of friction are taken, at which time the sliding speed shall be 65 mm per min.

The following shall be a cause for rejection of the bearing:

- Damage visible to the naked eye on disassembly of the bearing, such as excessive wear, cracks, or splits in the material.
- A coefficient of friction which exceeds two-thirds the value used in design.

16.5.2.10. Bearing Horizontal Force Capacity Fixed or Guided Bearings Only
One or more loading combinations, consisting of a horizontal and vertical service-load which could exist simultaneously in the structure, shall be selected. The vertical load shall be applied first, at 1.0 times its nominal value. The horizontal load shall be applied in stages, up to 1.5 times its nominal value. Failure or excessive deflection of any of the components shall because for rejection.

16.5.3. Performance Criteria
If one bearing of the sample fails, all the bearings of that lot shall be rejected, unless the Manufacturer elects to test each bearing of the lot at his expense. In lieu of this procedure, the Engineer may require every bearing of the lot to be tested.

16.5.4. Special Testing Requirements

16.5.4.1. Special Test Requirements for Elastomeric Bearings

1. General
Materials for elastomeric bearings and the finished bearings themselves shall be subjected to the tests described herein. Material tests shall be in accordance with either Table 16.1 or Table 16.2 as appropriate.

2. Frequency of Testing
The ambient-temperature tests on the elastomer specified in Article 16.5.4.1.3. "Ambient-Temperature Tests on the Elastomer" shall be conducted for the materials used in each lot of bearings. In lieu of performing a shear modulus test for each batch of material, the Manufacturer may elect to provide certificates from tests performed on identical formulations within the preceding year, unless otherwise specified by the
Engineer. Test certificates from the supplier shall be provided for each lot of reinforcement.

The three low-temperature tests on the elastomer specified in Article 16.5.4.1.4, "Ambient-Temperature Tests on the Elastomer" shall be conducted on the material used in each lot of bearings for Grades 3, 4 and 5 material and the instantaneous thermal stiffening test shall be conducted on material of Grades 0 and 2. For Grade 3 material, in lieu of the low-temperature crystallization test, the Manufacturer may choose to provide certificates from low-temperature crystallization tests performed on identical material within the last year, unless otherwise specified by the Engineer. Low-temperature brittleness and crystallization tests shall not be required for Grades 0 and 2 materials, unless especially requested by the Engineer.

Every finished bearing shall be visually inspected in accordance with the provisions of Article 16.5.4.1.5, "Visual Inspection of the Finished Bearing".

Every steel reinforced bearing shall be subjected to the short-term load test specified in Article 16.5.4.1.3, "Ambient-Temperature Tests on the Elastomer".

From each lot of bearings designed under the (MA-100-D-V2/2), a random sample shall be subjected to the long-term load test specified in Article 16.5.4.1.7, "Long-Duration Compression Tests on Bearings". The sample shall consist of at least one bearing chosen randomly from each size and material batch and shall comprise at least ten percent (10%) of the lot. If one bearing of the sample fails, all the bearings of that lot shall be rejected, unless the Manufacturer elects to test each bearing of the lot at the Manufacturer's expense. In lieu of this procedure, the Engineer may require every bearing of the lot to be tested.

The Engineer may require shear stiffness tests on material from a random sample of the finished bearings in accordance with the provisions of Article 16.5.4.1.8, "Shear Modulus Tests on Material from Bearings".

3. Ambient-Temperature Tests on the Elastomer

The elastomer used shall satisfy or exceed the criteria specified in the appropriate Table 16.1 and Table 16.2. The bond to the reinforcement, if any, shall also satisfy the provisions of Article 16.3.2.3, "Bond". The shear modulus of the material shall be tested at twenty-three degree Celsius (23°C) using the apparatus and procedure described in Annex A of ASTM D 4014. It shall fall within fifteen percent (15%) of the value specified in the contract documents. If no shear modulus is specified, the range of hardness shall conform to Article 12-6-6-5-2 of the (MA-100-D-V2/2).

4. Low-Temperature Tests on the Elastomer

Low-temperature tests shall be performed in accordance with the requirements of Table 16.1 and Table 16.2 and the compound shall satisfy all criteria for its grade.

5. Visual Inspection of the Finished Bearing

Each finished bearing shall be inspected for compliance with dimensional tolerances and for overall quality of manufacture. In steel reinforced bearings, the edges of the steel shall be protected everywhere from corrosion.

6. Short-Duration Compression Test on Bearings

The bearing shall be loaded in compression to one hundred and fifty percent (150%) of its rated service load. If a rotational element exists, a tapered plate shall be
introduced in the load train so that the bearing sustains the load at the maximum simultaneous design rotation. The load shall be held for 5 min, removed, and then reapplied for a second period of 5 min. The bearing shall be examined visually while under the second loading. If the load drops below the required value during either application, the test shall be restarted from the beginning.

The bearing shall be rejected if:

- The bulging pattern suggests laminate parallelism,
- A layer thickness is outside the specified tolerances,
- A poor laminate bond exists, or
- Three or more separate surface cracks greater than 2 mm wide and 2 mm deep exists.

7. Long-Duration Compression Tests on Bearings

The long-term compression test shall be conducted as specified in Article 16.5.4.1.3, "Ambient-Temperature Tests on the Elastomer", except that the second load shall be maintained for 15 hour. The bearing shall be visually examined at the end of the test while still under load. If any patterns or cracks specified in Article 16.5.4.1.3, "Ambient-Temperature Tests on the Elastomer", occur, the bearing shall be rejected.

8. Shear Modulus Tests on Material from Bearings

The shear modulus of a material in the finished bearing shall be evaluated by testing a specimen cut from it using the apparatus and procedure described in Annex A of ASTM D 4014, amended where necessary in Table 16.1 or Table 16.2, at the discretion of the Engineer, a comparable nondestructive stiffness test may be conducted on a pair of finished bearings. The shear modulus shall fall within fifteen percent (15%) of the specified value. If no shear modulus is specified in the contract documents, the range for hardness shall conform to Article 12.6.6.5.2 of the (MA-100-D-V2/2). If the test is conducted on finished bearings, the material shear modulus shall be computed from the measured shear stiffness of the bearings, taking due account of the influence on shear stiffness of bearing geometry and compressive load.

16.5.4.2. Special Test Requirements for Pot and Disc Bearings

1. Lot Size

Sampling, testing, and acceptance consideration shall be made on a lot basis. A lot shall be the smallest number of bearings as determined by the following criteria:

- Shall not exceed a single contract document or project quantity.
- Shall not exceed 25 bearings.
- Shall consist of those bearings of the same type regardless of load capacity. Bearing types may be fixed or expansion types, guided and non-guided expansion bearings shall be considered to be a single type.

2. Sampling and Testing Requirements

a. Material Certification Tests

The Manufacturer shall select, at random, samples for material certification tests as defined in Article 16.5.2.10, "Bearing Horizontal Force Capacity Fixed or Guided Bearings Only", and Article 16.5.2.2, "Material Certification Tests" bearings from
completed lots of bearings for testing by the Manufacturer. The Manufacturer shall complete the required testing and determine compliance with this specification before submitting the lot(s) for quality assurance inspection, testing, and acceptance consideration. The results of the Manufacturer's tests shall be furnished to the Engineer.

Certification shall be provided for all elastomeric and polyether urethane elements. Their material properties shall satisfy the requirements specified in the contract documents and the tests described in Article 16.7.1.2, "Installation" for pot bearings and Article 16.3.3.7, "Polyether Urethane Structural Element for Disc Bearings" for disc bearings. Additional tests may be required by the Engineer.

b. Testing by the Engineer

When quality-assurance testing is specified in the contract documents, the Manufacturer shall furnish to the Engineer the required number of complete bearings and component samples to perform quality-assurance testing in accordance with Table 16.5.

At least one elastomeric element shall be tested per lot of bearings for pot bearings and at least one set of material property tests shall be conducted per lot for disc bearings. All exterior surfaces of sampled production bearings shall be smooth and free from irregularities or protrusions that might interfere with testing procedures.

A minimum of 30 days shall be allowed for inspection, sampling, and quality-assurance testing of production bearings and component materials.

Bearings with tapered sole plates shall conform to the provisions of Article 16.5.1.3, "Tapered Sole Plates".

The Engineer may select, at random, the required sample bearing(s) from completed lots of bearings and samples of the elastomeric and PTFE materials for quality assurance testing.

The Contractor shall assume the cost of transporting all samples from the place of manufacture to the test site and back or, if applicable, to the project site.

<table>
<thead>
<tr>
<th>Test</th>
<th>Samples Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proof Load</td>
<td>One production bearing per lot</td>
</tr>
<tr>
<td>Coefficient of Friction</td>
<td>One production bearing per lot</td>
</tr>
<tr>
<td>Physical Properties of Elastomeric Rotational Element</td>
<td>One elastomeric element per lot</td>
</tr>
<tr>
<td>Physical Properties of PTFE Sheet</td>
<td>One 0.25 m×0.38 m sheet of PTFE material per project</td>
</tr>
<tr>
<td>Physical Properties of Polyether Urethane Structural Element (except compression set)</td>
<td>One 0.25 m×0.38 m sheet of polyether urethane material (thickness of 1.6 mm to 3.1 mm per lot)</td>
</tr>
<tr>
<td>Compression Set of Polyether Urethane Structural Element</td>
<td>One 0.10 m×0.10 m sheet of polyether urethane per lot, molded or cut to the thickness requirements of ASTM D 395, Method B</td>
</tr>
</tbody>
</table>
3. Performance Characteristics

a. Proof Load Test

Critical dimensions shall include the clearance between the piston and the pot and shall be verified by the clearance test described in Article [16.5.2.5], "Clearance Test".

A long-term deterioration test, as described in Article [16.5.2.9], "Long-Term Deterioration Test" shall be performed on one disc bearing of each lot and on one bearing of each lot of pot bearings with the sealing rings with rectangular cross-sections satisfying Article 12.6.6.4.5-B and sealing rings with circular cross sections satisfying the Article 12.6.6.4.5-C in the (MA-100-D-V2/2). The bearing shall be load-tested to one hundred and fifty percent (150%) of the specified rated capacity at an angle of 1.14 degrees. If the size of the bearing prohibits adequate testing with available equipment, the Owner and Manufacturer may agree to test a prototype bearing with comparable requirements.

During the test, the steel bearing plate and steel piston shall maintain continuous and uniform contact for the duration of the test.

The bearing shall be visually examined both during the test and upon disassembly after the test. Any resultant visual defects, such as extruded or deformed elastomer, polyether urethane, or PTFE; damaged seals or limiting rings; evidence of metal-to-metal contact between the pot wall and the top plate; or cracked steel, shall be a cause for rejection of the lot.

For disc bearings, continuous and uniform contact shall be maintained between the polyether urethane element and the bearing plates and between the sliding steel top plate and the upper bearing plate for the duration of the test. Any observed lift-off will be a cause for rejection of the lot.

b. Sliding Coefficient of Friction

For all guided and non-guided expansion-type bearings, the sliding coefficient of friction shall be measured at the bearing's design capacity in accordance with Article [16.5.4.5], "Special Testing for Bronze or Copper-Alloyed Plates for Bearings," and additionally on the fifth and fiftieth cycles, at a sliding speed of 25 mm per min.

The sliding coefficient of friction shall be calculated as the horizontal load required to maintain continuous sliding of one bearing, divided by the bearing's vertical design capacity.

The test results shall be evaluated as follows:

- The measured sliding coefficients of friction shall not exceed three percent (3%).
- The bearing will be visually examined both during and after the test. Any resultant visual defects, such as bond failure, physical destruction, cold flow of PTFE to the point of de-bonding, or damaged components, shall be a cause for rejection of the lot.

Bearings not damaged during the testing of performance characteristics may be used in the work.

16.5.4.3. Special Test Requirements for Rocker and Roller Bearing

Steel used in rocker and roller bearing shall be of the types and grades as specified in the contract documents. The steel at the contact surface of a metal bearing may be hardened provided that, after hardening, the steel satisfies the strength and ductility requirements of the contract documents and the material specification.
Fabrication shall be performed in a manner that conforms to the practice in modern commercial shops. Burrs, rough, and sharp edges, and other flaws shall be removed.

Lubrication shall be applied to all components of the roller bearing, and the type of lubricant shall be specified in the contract documents, and in accordance to the supplier guide.

16.5.4.4. Special Testing for Polytetrafluorethylene (PTFE) Surfaces for Bearings

Inspection of the completed bearings or representative samples of bearings with PTFE surfaces shall be required by the Engineer. Inspectors, if appointed, shall be allowed free access to the necessary part of the Manufacturer's plant and test facility. When testing is performed by the Manufacturer, copies of the test results shall be submitted to the Engineer.

The Manufacturer is required to perform material tests on the materials used in the sliding surface in accordance with Article 16.5.2.3, “material friction tests-sliding surface”. A minimum of one test shall be performed for each lot of bearings.

If requested by the Engineer and available test facilities permit, complete bearings shall be tested for complete bearing friction as defined in Article 16.5.2.10, "Bearing Horizontal Force Capacity". If the test facility does not permit testing complete bearings, at the direction of the Engineer, extra bearings may be manufactured by the Contractor and samples of at least 450 KN Capacity at normal working stresses prepared by sectioning the bearings. As soon as all bearings have been manufactured for a given project, notification shall be given to the Engineer who will select the prescribed test bearings at random from the lot. Manufacturer's certification of the steel, elastomeric pads, preformed fabric pads, PTFE, and other materials used in the construction of the bearings shall be furnished along with notification of fabrication completion.

Bearings represented by test specimens passing the above requirements shall be approved for use in the structure subject to on-site inspection for visible defects.

16.5.4.5. Special Testing Requirements for Bronze or Copper-Alloyed Plates for Bearings

Material certification tests for bronze or copper-alloy bearings shall be performed to verify the properties of the material.

16.5.4.6. Special Testing Requirements for Curved Sliding Bearing

Curved PTFE sliding surfaces shall satisfy all of the test requirements specified for PTFE sliding surfaces in Article 16.5.4.4 "Special Testing for Polytetrafluorethylene (PTFE) Surfaces for Bearings", except that, when the prototype bearing is too large to test, a test bearing may be especially manufactured using materials and fabrication methods that are identical to those used for the prototype, in lieu of sectioning a bearing. Because of the inability of test large bearings, the scaled model of the bearing shall be carefully decided by the Engineer.

Critical dimensions shall include the difference between the average radii of the two elements and the variation of the actual curved surface from the average one. The Engineer may require verification of these critical dimensions through a dimensional check as described in Article 16.5.2.4 "Dimension Check".
16.5.5. Use of Tested Bearing in the Structure

Bearings which have been satisfactorily tested in accordance with the requirements of this section may be used in the structure provided that they are equipped with new deformable elements, sliding elements and seals, as required by the engineer.

16.6. Packaging, Handling, and Storage

Prior to shipment from the point of manufacture, bearings shall be packaged in such a manner to ensure that during shipment and storage the bearings will be protected against damage from handling, weather, or any normal hazard. Each completed bearing shall have its components clearly identified, be securely bolted, strapped, or otherwise fastened to prevent any relative movement, and be marked on its top as to location and orientation in each structure in the project in conformity with the contract documents.

All bearing devices and components shall be stored at the work site in an area that provides protection from environmental and physical damage. When installed, bearings shall be clean and free of all foreign substances.

Dismantling of bearings at the site shall not be done unless absolutely necessary for inspection or installation. Bearings shall not be opened or dismantled at the site except for inspection or installation.

16.7. Installation

Bearings shall be installed by qualified personnel to the positions shown in the contract documents. Bearings shall be set at time of installation to the dimensions and offsets prescribed by the Manufacturer, by the Engineer, and as shown in the contract documents and shall be adjusted as necessary to take into account the temperature and future movements of the bridge due to temperature changes, release of Falsework, and shortening due to prestressing.

Each bridge bearing shall be located within ±3 mm of its correct position in the horizontal plane and oriented to within an angular tolerance of 1.14 degrees. Guided bearings and bearings which rotate about only one axis shall be oriented in the direction specified in the contract documents to within an angle tolerance of 0.28 degrees. All bearings except those which are placed in opposing pairs shall be set horizontal to within an angular tolerance of 0.28 degrees, and must have full and even contact with load plates, where these exist. The superstructure supported by the bearing shall be set so that, under full dead load, its slope lies within an angular tolerance of 0.28 degrees of the design value. Any departure from this tolerance shall be corrected by means of a tapered plate or by other means approved by the Engineer. If shim stacks are needed to level the bearing, they shall be removed after grouting and before the weight of the superstructure acts on the bearing.

Metallic bearing assemblies not embedded in the concrete shall be bedded on the concrete with a filler or fabric material conforming to Article 16.3.8, "Special Requirements for Bedding of Masonry Plates".

Where bearings are seated directly on steel work, the supporting surface shall be machined so as to provide a level and planar surface upon which the bearing is placed.

Bearings or masonry plates which rest on steel supports may be directly installed on the supports, provided the support is flat within a tolerance of 0.002 times the nominal dimension and is sufficiently rigid so as not to deform under specified loads.
Bearing types include, but are not limited to, elastomeric pad, rocker, roller, pot, spherical, disc, and sliding plate bearings. Included as components of bearings are masonry, sole and shim plates, bronze or copper-alloyed bearings and expansion plates, anchor bolts, guide devices, Polytetrafluorethylene (PTFE) sheets or surfacing, lubricants and adhesives.

16.7.1. Elastomeric Bearings

16.7.1.1. General

Elastomeric bearings as defined herein shall include unreinforced pads (consisting of elastomer only) and reinforced bearings with steel or fabric laminates.

Bearing shall be furnished with the dimensions, material properties, elastomer grade, and type of laminates specified in the contract documents. The design load shall be shown in the contract documents and testing shall be performed accordingly. Unless otherwise specified in the contract documents, bearings shall be Grade 3, 60-durometer elastomer, and steel reinforced, and shall be subjected to the load-testing requirements specified herein.

16.7.1.2. Installation

Elastomeric bearings without external load plates may be placed directly on a concrete or steel surface provided that it is flat to within a tolerance of 0.005 of the nominal dimension for steel reinforced bearings and 0.01 of the nominal dimension for others. Bearings shall be placed on surfaces that are horizontal to within 0.57 degrees. Any lack of parallelism between the top of the bearing and the underside of the girder that exceeds 0.57 degrees shall be corrected by grouting or as otherwise directed by the Engineer.

Exterior plates of the bearing shall not be welded unless at least 40 mm of the steel exists between the weld and the elastomer. In no case shall the elastomer or the bond be subjected to temperature higher than two hundred degree Celsius (200°C).

16.7.2. Pot and Disc Bearings

16.7.2.1. General

Pot and disc bearings shall be adequate for the design loads and movements shown in the contract documents or specified and shall be tested at the appropriate level.

16.7.2.2. Installation

Pot and disc bearings shall be installed in accordance with the contract documents and on the approved working drawings. Upon final installation of the bearings, the Engineer, in the presence of the Manufacturer's representative, shall inspect the bearing components to assure that they are level and parallel to within 2.6 mm/m. Any deviations in excess of the allowed tolerances shall be corrected.

16.7.3. Rocker And Roller Bearings

16.7.3.1. General

Lubrication shall be applied to all gear mechanisms and to all other components of roller bearings for which it is required. The type of lubricant shall be as specified on the
contract documents, and shall be applied in accordance with the Manufacturer's recommendations.

16.7.3.2. Installation

Setting of rocker and roller bearings shall take into account any variation from mean temperature of the supported span at time of setting and any other anticipated changes in length of the supported span so that at mean temperature, after release of falsework and any shortening due to pre-stressing force and shrinkage, the rockers and rollers will be vertical. Care shall be taken that full and free movement of the superstructure at movable bearings is not restricted by improper settings or adjustment of bearings.

The Contractor shall coat all contact surfaces thoroughly with oil and graphite prior to placing roller bearings.

Cylindrical bearings shall be positioned so their axes of rotation are in alignment and coincide with the axis of rotation of the superstructure.

16.7.4. Spherical Bearings

16.7.4.1. General

Spherical bearings shall be fabricated, tested, and installed as specified in the contract documents.

A spherical bearing is a bearing that permits angular rotation about a central point in two orthogonal directions within a specified angular limit based on the bearing geometry. Typically these bearings support a rotating shaft in the [bore] of the inner ring that must move not only rotationally, but also at an angle.

16.7.4.2. Construction

Construction of spherical bearings shall be hydrostatic or strictly mechanical. A spherical bearing by itself can consist of an outer ring and an inner ring and a locking feature that makes the inner ring captive within the outer ring in the axial direction only. The outer surface of the inner ring and the inner surface of the outer ring are collectively considered the raceway and they slide against each other, either with a lubricant or a maintenance-free PTFE [Teflon] based liner. Some spherical bearings incorporate a rolling element such as a race of ball-bearings, allowing lower friction.

16.7.4.3. Application

Spherical bearings are used in countless applications, wherever rotational motion must be allowed to change the alignment of its rotation axis. A prime example is a tie rod on a vehicle suspension. The mechanics of the suspension allow the axle to move up and down, but the linkages are designed to control that motion in one direction only and they must allow motion in the other directions. Spherical bearings have been used in Computer mice, car suspensions, trackballs, drives-hafts, heavy machinery, sewing machines, and many other applications.

16.7.5. Bronze or Copper-Alloyed Plates for Bearings

16.7.5.1. Bronze Bearing and Expansion Plates

Bronze bearing and expansion plates shall conform to the Specification for Bronze Castings for Bridges and Turntables, AASHTO M 107 (ASTM B 22) alloy C91100,
C86300, or C90500. Alloy C91100 shall be furnished unless otherwise specified in the contract documents. Components may be cast, rolled, or forged. Castings shall be free of blow-holes larger than 3 mm and contact surfaces shall be free of all blow-holes of any size. Bronze plates shall be cast according to details shown in the contract documents. Sliding surfaces shall be planed parallel to the movement of the spans and polished unless detailed otherwise in the contract documents.

16.7.5.2. Rolled Copper-Alloy Bearings and Expansion Plates

Rolled copper-alloy bearing and expansion plates shall conform to the Specification for Rolled Copper-Alloy Bearing and Expansion Plates and Sheets for Bridge and Other Structural Uses, AASHTO M 108 (ASTM B 100). Alloy C51000 or C51100 shall be furnished unless otherwise specified in the contract documents.

Copper-alloy plates shall be furnished according to details shown in the contract documents. Finishing of the rolled plates shall not be required provided they have a plane, true, and smooth surface.

16.7.6. Masonry, Sole, and Shim Plates for Bearings

Holes in bearing plates may be formed by drilling, punching, or accurately controlled oxygen-cutting. All burrs shall be removed by grinding.

Bearing plates shall be accurately set in level position as shown in the contract documents and shall have a uniform bearing over the whole area. When plates are to be embedded in concrete, provision shall be made to keep the plates in correct position as the concrete is being placed.

16.7.7. Polytetrafluoroethylene (PTFE) Surfaces for Bearings

16.7.7.1. General

PTFE sheet and strip shall be manufactured either from pure virgin (not reprocessed), unfilled PTFE resin; from PTFE resin uniformly blended with either fifteen percent (15%) glass fiber or twenty-five percent (25%) carbon (maximum filler, percent by weight); or from fabric containing PTFE fibers.

Horizontally installed PTFE sheet shall be bonded to and recessed into its steel substrate. Vertically installed PTFE sheet shall be bonded to and recessed into or bonded to and mechanically fastened to its steel substrate. PTFE sheet shall have a minimum thickness of 3 mm and shall be recessed for at least one-half of its thickness into its steel substrate.

Finished PTFE sheet and strip shall be resistant to all acids, alkalis, and petroleum products; stable at temperatures from minus two hundred degree Celsius and eighteen up to two hundred and sixty degree Celsius (-218°C to 260°C); nonflammable; and non-absorbing of water. The epoxy used to bond the PTFE to its steel substrate shall be a heat cured high-temperature epoxy capable of withstanding temperatures of minus one hundred and ninety six degree Celsius up to two hundred and sixty degree Celsius (-196°C to 260°C).

Expansion bearings shall be manufactured to the dimensions and to meet the requirements of the method of fastening to the structure as shown in the contract documents.
16.7.7.2. Attachment of PTFE Material

When mechanically fastened, PTFE sheet shall be fastened as shown in the contract documents with the size, type, and number of fasteners required. The fastener used in the PTFE sheet and back-up material shall be installed to provide full bearing.

1. Flat Sheet PTFE

All flat sheet PTFE attached to a metal backing plate shall be attached by recessing into the backing of the plate for one-half of the PTFE thickness and bonding. PTFE attached to other materials, such as elastomers, shall be attached by a method specified in the contract documents or approved by the Engineer.

The PTFE shall be factory-bonded, using an adhesive that is approved by the Engineer, in accordance with the instructions of the adhesive's Manufacturer. Prior to bonding, the surface shall be etched by an approved Manufacturer using sodium naphthalene or sodium ammonia process. When the backing plate is metal, the bonding shall be conducted under a uniform pressure greater than 0.7 MPa.

The peel strength of the bond shall not be less than 3.5 N/mm, tested in accordance with ASTM 0429, Method B. The finished surface of the PTFE shall be smooth, free from bubbles, and shall conform to the tolerances shown in Table 16.4. Filled PTFE sheets shall be polished after bonding.

2. Curved Sheet

Curved sheet PTFE, such as used in spherical bearings, shall be attached by recessing for one-half the PTFE thickness. The dimensions of the PTFE element shall be selected so that it fits tightly in the recess even when the bearing is subjected to its lowest design temperature.

3. Fabric Containing PTFE Fibers

Fabric made from woven PTFE fibers shall be bonded or mechanically attached to a rigid substrate. The fabric shall be capable of carrying unit stress of 70 MPa without cold flow. The fabric-substrate bond shall be capable of withstanding, without delamination, a shear force equal or greater than \((0.1+\mu)P\) at the same time as the normal load \(P\), where \(\mu\) is the design coefficient of friction between the PTFE and its mating surface and \(P\) is the design load acting perpendicularly to the interface.

16.7.7.3. Stainless Steel Mating Surface

Each stainless steel element specified in the contract documents as a single piece shall be so supplied. Each sheet shall be attached to its backing material by seal welding around the entire perimeter so as to prevent entry of moisture between the stainless steel and the backing material. Welds shall conform to the current AASHTO/AWS 0 1.5M/D 1.5 Bridge Welding Code. After welding, the stainless steel sheet shall be flat, free from wrinkles and in continuous contact with its backing plate.

16.7.7.4. Lubrication

Lubrication shall be applied to the entire PTFE surface if specified in the contract documents or by the Engineer. If the PTFE is dimpled, enough lubricant shall be applied to fill all the dimples.
16.7.7.5. Installation

Installation shall be performed as specified in Article 16.7.3.2, "Installation".

16.7.8. Anchor Bolts

The Contractor shall drill holes for anchor bolts and set them in portland cement grout, or preset them as shown in the contract documents or as specified or directed by the Engineer.

Location of anchor bolts shall take into account any variation from mean temperature of the superstructure at time of setting and anticipated lengthening of bottom chord or bottom flange due to dead load after setting; the intention being that, as near as practicable, at mean temperature and under dead load, the anchor bolts at expansion bearings will center their slots. Care shall be taken that full and free movement of the superstructure at movable bearings is not restricted by anchor bolts or nuts.

16.7.9. Load Plates

Load plates shall be made from a single plate or they may be built up from several steel laminates, each oriented in the plane perpendicular to the direction of the load. Built-up load plates shall be joined by complete seal welding to prevent ingress of moisture. Such welds shall also provide sufficient shear strength to resist the applied loads. The load plates shall have no sharp corners or edges. Holes may be formed by drilling, punching, or accurately controlled oxygen cutting. All burrs shall be removed by grinding.

16.7.10. Other Requirements for Guides

Guide bars shall be attached to the body of the bearing by a method which minimizes distortion and allows the flatness tolerance on all parts of the bearing to be met after attachment. The sliding surfaces of the guide system shall be flat and parallel.

Bolts or threaded fasteners used to attach the guide bars to their supporting plates shall have an embedded thread length adequate to develop their strength.

If low-friction material is used at the contact interface, it shall be attached to its backing piece by two or more of the following methods simultaneously:

- bonding,
- Recessing, and
- Mechanical attachment with countersunk fasteners.

If the material is bonded, it shall be fixed by the method recommended by the Manufacturer of the material or bonding agent. Recessing shall be one-half of the material thickness. Fasteners shall be countersunk to a depth which ensures that they will not touch the mating material after allowing for wear.

16.7.11. Installation for Guide-ways and Restraints

Guided bearings and bearings which rotate about only one axes shall be oriented in the direction specified on the contract plans to within an angular tolerance of 0.3 degree.
Measurement and Payment

16.8. Measurement and Payment

16.8.1. Measurement

Bearing devices shall be measured either by the kilogram as determined from scale weight or by a unit basis for each type of bearing assembly listed in the contract documents. Scale weight is not required when calculated weight is shown in the contract documents, in which case the weight shown in the contract documents shall be used as the basis of payment.

16.8.2. Payment

Bearing devices shall be paid for at the contract price per kilogram or per unit. Such payment shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in furnishing, testing, and installing said bearing devices, complete in place, as shown in the contract documents, as specified in these Specifications, and as directed by the Engineer.

Payment will be made as indicated in Table 16.6. Table 16.7 shows quality control requirements.

<table>
<thead>
<tr>
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<tr>
<td>16.3.1</td>
<td>Bearing Devices</td>
<td>Kilograms or Unit</td>
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Table 16.6: Bearing Devices Pay Items

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<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
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<tbody>
<tr>
<td>Placing</td>
<td>Elastomeric bearings</td>
<td>Visual inspection and measurement</td>
<td>In situ</td>
<td>Each</td>
<td>Article 16.7.1.2</td>
</tr>
<tr>
<td></td>
<td>Pot and disc bearings</td>
<td>Visual inspection and measurement</td>
<td>In situ</td>
<td>Each</td>
<td>Article 16.7.2.2</td>
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<tr>
<td></td>
<td>Rocker and roller bearings</td>
<td>Visual inspection and measurement</td>
<td>In situ</td>
<td>Each</td>
<td>Article 16.7.3.2</td>
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</table>

Table 16.7: Quality Control Requirements For Bearing Devices

<table>
<thead>
<tr>
<th>Work</th>
<th>Designations/Specifications/Standards</th>
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<tbody>
<tr>
<td>Placing</td>
<td>AASHTO M 270/M 270</td>
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<tr>
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<td>ASTM A 709/A 709M</td>
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<tr>
<td></td>
<td>Article 16.7.1.2</td>
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<td></td>
<td>Article 16.7.2.2</td>
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<td>Article 16.7.3.2</td>
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Table 16.8: AASHTO and ASTM Designation and its Title

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<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
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<tr>
<td>as specified</td>
<td>AASHTO M 270/M 270</td>
<td>ASTM A 709/A 709M</td>
<td>Work Item: Standard Specification for Structural Steel for Bridges</td>
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<td>as specified</td>
<td>ASTMA 802/A 802M</td>
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<td>Standard Practice for Steel Castings, Surface Acceptance Standards, Visual Examination</td>
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<tr>
<td>Section 16: Bearing Devices</td>
<td>Measurement and Payment</td>
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<td><strong>as specified</strong></td>
<td>ASTM A 1011/A 1011M</td>
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<td>Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength</td>
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<td><strong>as specified</strong></td>
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<td>Standard Specification for Steel Forgings, General Requirements</td>
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<td>ASTM A 167, Type 304</td>
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<td>Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip</td>
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<td><strong>as specified</strong></td>
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<td>Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications</td>
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<td><strong>as specified</strong></td>
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<td>Standard Specification for Plain and Steel-Laminated Elastomeric Bearings for Bridges</td>
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<td><strong>see table 16-1</strong></td>
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<td>Standard Test Method for Rubber Property—Durometer Hardness</td>
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<td><strong>see table 16-1</strong></td>
<td>ASTM D 412</td>
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<td>Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension</td>
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<td>ASTM D 573</td>
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<td>Standard Test Method for Rubber—Deterioration in an Air Oven</td>
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<td><strong>see table 16-1</strong></td>
<td>ASTM D 395, Method B</td>
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<td>Standard Test Methods for Rubber Property—Compression Set</td>
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<td><strong>see table 16-1</strong></td>
<td>ASTM D 1149</td>
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<td>Standard Test Methods for Rubber Deterioration-Cracking in an Ozone Controlled Environment</td>
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<td><strong>see table 16-1</strong></td>
<td>ASTM D 746, Procedure B</td>
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<td>Standard Test Method for Brittleness Temperature of Plastics and Elastomers by Impact</td>
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<td><strong>see table 16-1</strong></td>
<td>ASTM D 1043</td>
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<td>Standard Test Method for Stiffness Properties of Plastics as a Function of Temperature by Means of a Torsion Test</td>
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<td><strong>for vulcanized bond between fabric and reinforcement (minimum peel strength of 5.3 N/mm). for Steel laminated bearings (minimum peel strength of 7.0 N/mm)</strong></td>
<td>ASTM D 429</td>
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<td>Standard Test Methods for Rubber Property—Adhesion to Rigid Substrates</td>
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<td><strong>see table 16-1</strong></td>
<td>AASHTO M251</td>
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<td>ASTM D4014</td>
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<tr>
<td>Standard Specification for Plain and Steel-Laminated Elastomeric Bearings for Bridges</td>
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### References

**Section 16: Bearing Devices**

| as specified | ASTM B 36/B 36M | Standard Specification for Brass Plate, Sheet, Strip, And Rolled Bar |
| as specified | ASTM B 121/8 121M | Standard Specification for Leaded Brass Plate, Sheet, Strip, and Rolled Bar |
| as specified | ASTM D4894 | Standard Specification for Polytetrafluoroethylene PTFE Granular Molding and Ram Extrusion Materials |
| see table 16-4 | ASTM D 638 | Standard Test Method for Tensile Properties of Plastics |
| see table 16-4 | ASTM D 792 | Standard Test Methods for Density and Specific Gravity Relative Density of Plastics by Displacement |
| see table 16-4 | ASTM D 4894 | Standard Specification for Polytetrafluoroethylene PTFE Granular Molding and Ram Extrusion Materials |
| see table 16-4 | ASTM D 5977 | Standard Specification for High Load Rotational Spherical Bearings for Bridges and Structures |
| see table 16-4 | ASTM D 2256 | Standard Test Method for Tensile Properties of Yarns by the Single-Strand Method |
| as specified | AASHTO M 108 | ASTM B 100 | Standard Specification for Wrought Copper-Alloy Bearing and Expansion Plates and Sheets for Bridge and Other Structural Use |
| as specified | ASTM B 103/B 103M | Standard Specification for Phosphor Bronze Plate, Sheet, Strip, and Rolled Bar |
| as specified | ASTM A 307 | Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength |
| as specified | ASTM B 29 | Standard Specification for Refined Lead |
| as specified | ASTM C 920 | Standard Specification for Elastomeric Joint Sealants |
| as specified | ASTM D 4014 | Standard Specification for Plain and Steel-Laminated Elastomeric Bearings for Bridges |
| as specified | AASHTO M 107 | ASTM B 22 | Standard Specification for Bronze Castings for Bridges and Turntables |
| as specified | AASHTO M 108 | ASTM B 100 | Standard Specification for Wrought Copper-Alloy Bearing and Expansion Plates and Sheets for Bridge and Other Structural Use |

**16.9. References**


SECTION 17. BRIDGE DECK JOINT SEALS

17.1. General

This work shall consist of the furnishing and installing of joint sealing systems in bridge decks of the types used where significant movements are expected across the joint. These include compression seal joints consisting of preformed elastomeric material compressed and installed in specially prepared joints and joint seal assemblies consisting of assemblies of metal and elastomeric materials installed in recesses in the deck surface.

Joint seals specified in the contract documents as poured joint seals shall conform to the requirement of Article 10.11, "Expansion and Contraction Joints".

The type and dimensions or movement rating for bridge deck joint seals at each location shall be as shown in the contract documents or as ordered by the Engineer.

All joint seals shall prevent the intrusion of material and water through the joint system.

17.2. Working Drawings

If not given in the contract documents, calculations showing the joint settings for their installation shall be required before approval to install joints in any bridge deck can be granted. The Contractor shall submit working drawings to the Engineer showing the installation procedure and joint assembly for bridge decks using proprietary joint systems. Shop drawings shall be submitted to the Engineer for approval for joints having a total movement of more than 45 mm.

No work on the deck joint seal shall be performed prior to approval of working drawings by the Engineer. Such approval shall not relieve the Contractor of any responsibility under the contract documents for the successful completion of the work.

17.3. Materials

Bridge deck joint seal materials and assemblies shall conform to the following specifications:

Preformed elastomeric joint seals of multiple web design shall conform to AASHTO M 220, (ASTM D 2628).

Lubricant-adhesive for use with preformed elastomeric seals shall conform to ASTM D 4070.

Deck joint seal assemblies shall be of an approved type for each size required and shall conform to the specifications provided by the Manufacturer at the time of approval.

Steel and fabricated steel components shall conform to the requirements of Section 22, "Miscellaneous Metal."
17.4. Manufacture and Fabrication

17.4.1. Compression Seal Joints

Preformed elastomeric joint seals shall not be field spliced, except when specifically permitted by the Engineer.

17.4.2. Joint Seal Assemblies

Expansion joint assemblies shall be fabricated by the Manufacturer and delivered to the bridge site completely assembled, unless otherwise specified in the contract documents.

17.5. Installation

17.5.1. General

All joint materials and assemblies, when stored at the job site, shall be protected from damage and assemblies shall be supported so as to maintain their true shape and alignment. Deck joint seals shall be constructed and installed to provide a smooth ride. Bridge deck joints shall be covered over by protective material after installation until final cleanup of the bridge deck.

After installation and prior to final acceptance, deck joint seals shall be tested in the presence of the Engineer for leakage of water through the joint. Any leakage of the joint seal shall be a cause for rejection.

17.5.2. Compression Seal Joints

Joints in the roadway area of bridge decks that are to be sealed with compression seals shall be cast to a narrower width than required for the preformed material. Such joints in curbs and sidewalks may be cast to full width. Prior to installation of compression seals in joints whose width is narrower than needed, a groove of proper width and depth to receive the preformed material shall be saw cut along the top of the joint.

When making saw cuts into the bridge deck, spalling shall be minimized. Both sides of a groove shall be cut simultaneously to the proper depth and alignment as shown in the contract documents. The alignment of the saw shall be controlled at all times by a rigid guide. The width of the groove shall depend on the temperature and age of the concrete and shall be as directed by the Engineer. Lip of saw cut should be bevelled to avoid later breakage. After saw cutting, any spalls, popouts, or cracks shall be repaired prior to installation of the lubricant sealant. Saw cuts are not required where armor plates are used.

At the time of installation, the joint shall be clean and dry, and free from spalls and irregularities that might impair a proper joint seal. Concrete or metal surfaces shall be clean and free of rust, laitance, oils, dirt, dust, or other deleterious materials. Premolded elastomeric compression joint seals shall be installed without damage to the seal by suitable hand methods or machine tools. The lubricant adhesive shall be applied to both faces of the joint prior to installation and in accordance with the Manufacturer's instructions. The preformed elastomeric seal shall be compressed to the thickness specified in the contract documents or as approved by the Engineer for the rated
opening and ambient temperature at the time of installation. Loose fitting or open points between the seal and the deck shall not be permitted.

17.5.3. Joint Seal Assemblies

Expansion joint seal assemblies shall be constructed to provide absolute freedom of movement through the range shown in the contract documents or as prescribed by the engineer. Installation shall be in accordance with the Manufacturer's recommendations. Final settings of the deck joint seal assembly at the time of casting in the anchorages of the unit depend on the relationship of the current temperature of the superstructure to its expected mean temperature and shall be as specified by the Manufacturer or Engineer or as shown in the contract documents.

17.6. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and this section requirements. For work acceptance, Contractor shall apply quality control for bridge deck joint seals work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.

17.6.1. Quality Control

The bridge deck joint seals work should be controlled and all working drawing showing the installation procedure and joint assembly for bridge decks should be reviewed to insure that the contractor will follow it in correct way according to the article 17.2. All materials used in sealing the joints should meet the specification stipulated in article 17.3 and Table 17.3.

For work acceptance the installation work procedure should be inspected to meet the shop drawing and required specification of installation mentioned in the articles 17.4 and 17.5 according to the joint type.

17.6.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of deck joint sealing work, by reviewing the manufacturing certificates coming with the importing materials and installation procedure works, are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that insure the quality of all works that was finished according to the required tests mentioned in the related sections.

17.7. Measurement and Payment

Deck joint seals shall be measured by the linear meter of acceptable joint seal completely installed by measurements made along the slope of the centerline of the joint seal.

Payment of linear meters of joint seal as measured, for each type of seal for which separate payment is provided, shall include full compensation for the cost of labor, equipment, and materials to furnish and install the deck joint seal.

Payment will be made as indicated in Table 17.1. And the quality control requirements for bridge deck joint seals are shown in Table 17.2.
Table 17.1: Bridge Deck Joint Seals Pay Items

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<td>17.1</td>
<td>Deck Joint Seals</td>
<td>Linear Meter</td>
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Table 17.2: Quality Control Requirements For Bridge Deck Joint Seals

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<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
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<tbody>
<tr>
<td>Deck Joint Seals</td>
<td>Test for leakage of water</td>
<td>By pouring water</td>
<td>In situ</td>
<td>Each</td>
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Table 17.3: AASHTO and ASTM Designation and its Title

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<td>Standard Specification for Adhesive Lubricant for Installation of Preformed Elastomeric Bridge Compression Seals in Concrete Structures</td>
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<td>as specified</td>
<td>AASHTO M 220</td>
<td>ASTM D 2628</td>
<td>Standard Specification for Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements</td>
</tr>
</tbody>
</table>

17.8. References
SECTION 18. RAILINGS

18.1. General

This work shall consist of furnishing all materials and constructing railings on structures. Railings constructed at each location shall conform to the type and details specified in the contract documents for that location. The work shall include the furnishing and placing of mortar or concrete, anchor bolts, reinforcing steel dowels, or other attachment devices used to attach the railing to the structure.

All materials not otherwise specified in the contract documents shall conform to the requirements of the applicable AASHTO material specifications.

Unless otherwise permitted by the Engineer, railing shall not be placed until the centering or falsework for the span has been released, rendering the span self-supporting.

The line and grade of the railing shall be true to that specified in the contract documents and may include an allowance for camber in each span but shall not follow any unevenness in the superstructure. Unless otherwise specified in the contract documents, railings on bridges, whether super-elevated or not, shall be vertical.

18.2. Materials And Construction Requirements

18.2.1. Steel Railing

18.2.1.1. W-Beam or Thrie-Beam Railing

Materials and fabrication of steel railings shall conform to the applicable requirements of Section 13, "Steel Structures," except that formed sections may be fabricated from mild steel and pipe sections shall be of standard steel pipe. Nuts and bolts not designated as high strength shall conform to the requirements of ASTM A307, and steel tubing shall conform to the requirements of ASTM A 500, Grade B.

Rail elements and backup plates for W-Beam or Thrie-Beam rail shall conform to the requirements of AASHTO M180, Class A, Type 2 galvanized.

Unless otherwise indicated on the plans, all steel posts, plates, angles, channels, brackets, and anchor assembly units shall conform to the requirements of ASTM A 36. Cold rolled post sections shall conform to the requirements of ASTM A 446, Grade B.

All bolts shall conform to the requirements of ASTM A 307, except those designated on the plans as high strength shall conform to the requirements of ASTM A 325 or A 449. All nuts shall conform to the requirements of ASTM A 563, Grade A or better, except those designated on the plans as high strength shall conform to the requirements of ASTM A 563, Grade C or better.

Railing shall be installed at the locations shown in the contract documents or as ordered by the Engineer.

18.2.1.2. Wire Rope Railing

The ropes shall be of 19 mm diameter coreless construction having a minimum breaking load of 177 kN. The rope shall exhibit a minimum modulus of elasticity of
83000 MPa based on an area of 283 mm², after prestressing by an approved method to ensure the ropes behave elastically and retain their tension in service.

All wire used for the manufacture of the ropes shall be general purpose wire to AASHTO M30, Type II, finally zinc coated by the hot dip method.

All threaded terminals and rigging screws shall be hot dip galvanized according to AASHTO M232.

The installation of the cable railing shall be in accordance with the manufacturer's instructions and working drawings.

Continuous lengths of rail or cable shall be installed and alignment checked and adjusted before final tightening of bolts, etc. Unless otherwise specified, bolted connections shall be torqued to (60 to 70) N.m. Bolts that extend at least 6 mm but not more than 25 mm beyond the nuts shall be used.

The railing ropes shall be joined together by rigging screws, which are also used for tensioning. The maximum length of any one individual rope shall be 154 m. Immediately prior to each anchorage there shall be a tail rope 6 m in length and connected to the anchorage in the ground. All ropes shall be fitted on each end with a threaded terminal of right hand or left hand thread as appropriate to ensure a right hand and left hand thread is in the rigging screw to effect the tension. A minimum insertion of 25 mm into the rigging screw is required. The tail rope shall have a right hand thread on the end which is connected to the anchor.

When all the components are in place, the ropes shall be uniformly tensioned to 25 kN by turning the rigging screws. Backfill above the tops of concrete anchor footings shall not be placed before the cables are tensioned.

A check rope, 1.8 m in length, 8 mm diameter, with a minimum breaking load of 39 kN when tested as an assembly, fitted with a galvanized thimble at one end and a fork terminal at the other, shall be provided at each anchor. The thimble shall be passed over the end of the tail rope and the fork terminal connected to the anchor.

Equivalent galvanized wire rope with a minimum breaking strength of 194 kN will be acceptable.

18.2.1.3. Pipe Railing

1. Galvanized Steel Pipe and Fittings

Galvanized steel pipe and fittings shall meet the requirements of ASTM A 53, standard weight pipe. The requirement for hydrostatic testing shall be waived.

2. Black Steel Pipe and Fittings

Black steel pipe and fittings shall comply with the requirements of ASTM A 53, standard weight pipe. The requirement for hydrostatic testing shall be waived.

18.2.1.4. Welding

All exposed welds shall be finished by grinding or filing to give a smooth surface. Welding of aluminum materials shall be done by an inert gas shielded, electric arc welding process using no welding flux. Torch- or flame-cutting of aluminum will not be permitted.
18.2.1.5. Finish

Unless otherwise specified in the contract documents, anchor bolts, nuts, and all steel portions of railings shall be galvanized and aluminum portions shall not be painted. Galvanizing of rail element shall conform to the requirements of AASHTO Mill M/M III (ASTM A 123/A 123M) and galvanizing of nuts and bolts shall conform to the requirements of AASHTO M 232M/M 232 (ASTM A 153/A 153M). Minor abrasions to galvanized surfaces shall be repaired with zinc-rich paint. After erection, all sharp protrusions shall be removed and the railing cleaned of discoloring foreign materials.

When painting is specified in the contract documents, the type and coating shall conform to the requirements of Section 15, "Painting," or the requirements specified in the contract documents.

Damaged galvanized surfaces may be repaired, only if so approved by the Engineer. Such surfaces shall be repaired by thoroughly wire brushing and then by applying 2 coats of an approved zinc-dust zinc-oxide primer.

Finish for concrete railings constructed with fixed forms shall be Class 2-Rubbed Finish. Finish for railings constructed with slip forms and for temporary railings shall be Class 1-Ordinary Finish.

18.2.1.6. Installation

Rail elements shall be constructed to specified line and grade. All bolts, except adjustment bolts, shall be tightened. Bolt extension shall be limited to 10 mm beyond the nuts.

Rail elements to be erected on a radius of 45 m or less shall be shaped in the shop. The radius of curvature shall be stenciled on the back of each section of rail. Rail elements shall be designed to be spliced in the direction of traffic flow at intervals not exceeding 4 or 8 m. Such splices shall be made at posts, unless otherwise shown in the contract documents.

Metal railings shall be carefully adjusted prior to fixing in place to ensure proper matching at abutting joints, correct alignment, and camber throughout their length. Holes for field connections shall be drilled with the railing in place on the structure at proper grade and alignment.

Where aluminum alloys come in contact with other metals or concrete, the contacting surfaces shall be thoroughly coated with a dielectric aluminum-impregnated caulking compound or a synthetic rubber gasket may be placed between the two surfaces.

18.2.2. Aluminum Railing

For aluminum railings or portions of railings, cast aluminum posts shall conform to the requirements of AASHTO M 193 and extruded components shall conform to the requirements of ASTM B 221 (ASTM B 221M).

18.2.3. Metal beam railing

Metal beam rail, post, and hardware shall conform to the requirements in section 606 of the AASHTO guide specification for highway construction, section 606.

---

1 Surface finishes for formed concrete surfaces are described in Article 10.14, "Finishing Formed Concrete Surfaces".
18.2.4. Concrete Railings

Concrete railings, depending on the design, may be constructed by the cast-in-place, the precast, or, when approved by the Engineer, the slip form method.

All materials and construction shall conform to the requirements in Section 10, "Concrete Structures," and Section 11, "Reinforcing Steel". Unless otherwise specified in the contract documents, concrete shall conform to Class A. When the minimum thickness of the railing at any point is less than 100 mm, Class C shall be used. Forms for cast-in-place railing shall not be removed until adequate measures to protect and cure the concrete are in place and the concrete has sufficient strength to prevent surface or other damage caused by form removal.

18.2.5. Temporary Railing

Temporary railings shall be constructed of materials and to the details specified in the contract documents. Railings shall be properly joined and aligned at the required locations. Temporary precast barriers shall be installed on a solid base. The temporary railing shall be maintained in first-class condition and shall not be removed until all work requiring the railing has been completed. Previously used units may be employed provided they are in a clean and undamaged condition. After removal, temporary railing shall continue to be the property of the Contractor.

18.2.6. Railings Accessories and Reinstallation of Railings

Metal beams, cables, posts, anchor terminal sections, concrete barriers or safety railings shall be salvaged materials, as provided by the Ministry or as salvaged by the Contractor and approved by the Engineer.

Bolts, nuts, washers, fittings, adhesives, and accessories shall be new materials conforming to the requirements for the construction of new railing, concrete barrier and steel safety railing as detailed in Section 13, "Steel Structures" in these General Specifications.

Railing anchor terminals shall be installed at the locations shown on the plans or ordered by the Engineer.

The swage fittings for anchor terminals shall be machined from hot-rolled carbon steel conforming to the requirements of ASTM A 576, Grade 1035, and shall be annealed suitable for cold swaging. A lock pin hole shall be drilled through the swage fitting head to accommodate a seven millimeter, plated, spring steel pin to retain the stud in the proper position. The stud shall be steel conforming to the requirements of ASTM A 449. Prior to galvanizing, a ten millimeter slot for the locking pin shall be milled into the stud end. The swage fitting, stud, and nut shall develop the full breaking strength of the wire cable.

Anchor rod eyes shall be hot forged or formed with full penetration welds. After fabrication, anchor rods with eyes that have been formed with any part of the eye below eight hundred and seventy degree Celsius (870°C) during the forming operation or with eyes that have been closed by welding shall be thermally stress relieved prior to galvanizing. The completed anchor rod, after galvanizing, shall develop a pull strength of 230 kN.

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1 Classes of concrete are described with details in Article 10.3, "Classes of Concrete".
2 Time of removal of forms is covered in Article 6.2.5.2, "Time of Removal".
Clevises shall be drop forged galvanized steel and shall develop the full specified breaking strength of the wire cable.

The concrete insert assembly for Type 4 anchor terminals shall be fabricated as shown on the plans. Ferrules shall be steel conforming to the requirements of ASTM A108, Grade 12 L 14. Inserts shall be tapped to the dimensional requirements specified in ASTM A 563 for nuts receiving galvanized bolts. Insert assembly wires shall conform to the requirements of ASTM A 510, Grade 1030, and have a minimum tensile strength of seven thousand 700 MPa. Welded attachment of wire to ferrule shall develop the full tensile strength of the wire.

Turnbuckles shall be steel of commercial quality and shall have a minimum breaking strength of fifteen 15 kN. Turnbuckles shall be galvanized in accordance with ASTM A 153. Compensating and non-compensating cable ends shall be cast steel conforming to the requirements of ASTM A 27 or malleable iron conforming to the requirements of ASTM A 47. Compensating devices shall have spring constants of (80±5) kN/m and permit a travel of (150±25) mm. All elements shall be galvanized.

The cable connecting hardware shall develop the full strength of the wire rope. At all locations where the cable is connected to a cable end with a wedge type connection, one wire of the wire rope shall be crimped over the base of the wedge to hold the cable firmly in place.

18.3. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and this section requirements. For work acceptance, Contractor shall apply quality control for railings work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.

18.3.1. Quality Control

The Railings and crashworthy safety barriers should be inspected, sampled, tested and evaluated in accordance with article 3.5.1 in these General Specifications as follows:

The materials incorporated into the safety barriers shall be sampled, tested and evaluated. The installation of the safety barriers should be accepted in accordance with article 3.5.1 in these General Specifications.

Only components complying with the manufacturer's specification may be used. Copies of certificates of guarantee and test reports shall be provided for the components of each railing system manufactured off site.

18.3.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of railings work, that are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that insure the quality of all works that was finished according to the required tests mentioned in the related sections and the manufacturer requirements.
18.4. Measurement And Payment

18.4.1. Measurement

Railings shall be measured by the linear meter between the ends of the railing or the outside ends of end posts, whichever is greater. Measurements shall be made along the slope of the railing and no deductions shall be made for electrolier or other small openings called for in the contract documents.

18.4.2. Payment

Railings shall be paid for by the contract prices per linear meter for the various types listed in the contract documents. Such payment shall include full compensation for furnishing all labor, materials, equipment, and incidentals and for doing all works involved in constructing the railings or barriers complete in place, including the furnishing and installation of reinforcing steel and steel dowels or anchor bolts which are either placed or drilled and bonded into the structure for attachment of the railing.

Payment will be made as indicated in Table 18.1. And quality control requirements for railings are shown in Table 18.2.

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<td>Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength</td>
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<td>Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes</td>
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<td>Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless</td>
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<td>AASHTO Mill M/M III</td>
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<td>Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products</td>
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<td>Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware</td>
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<td>ASTM DESIGNATION</td>
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<td>ASTM B 221</td>
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<td>Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes</td>
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<td>ASTM A 576</td>
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<td>Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality</td>
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<td>ASTM A 449</td>
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<td>Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use</td>
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<td>Standard Specification for Steel Bar, Carbon and Alloy, Cold-Finished</td>
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<td>Standard Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel</td>
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<td>ASTM A 153</td>
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<td>Standard Specification for Zinc Coating Hot-Dip on Iron and Steel Hardware</td>
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<td>ASTM A 27</td>
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<td>Standard Specification for Steel Castings, Carbon, for General Application</td>
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<td>as specified</td>
<td>ASTM A 47</td>
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<td>Standard Specification for Ferritic Malleable Iron Castings</td>
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</table>
18.5. References

"Oklahoma Department of Transportation Standard Specifications for Highway Construction" - Sec. 504


MOT KSA:"General Specifications For Road And Bridge Construction"; November 1998. Sec. 6.01.

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SECTION 19. WATERPROOFING

19.1. General
This work shall consist of provision and installation of materials to waterproof or damp-proof for the concrete or masonry surfaces. The surfaces to be waterproofed or dampproofed and the type of system to be installed shall be as specified in the contract documents.

19.1.1. Waterproofing
Waterproofing shall consist of either a constructed in place asphalt membrane system or a preformed membrane system, both of which include appropriate priming materials and, when required, protective coverings. Unless a specific type of waterproofing system is specified in the contract documents, the type of system to be used shall be approved by the Engineer.

19.1.2. Dampproofing
Dampproofing shall consist of a coating of primer and two mopping of waterproofing asphalt.

19.2. Materials

19.2.1. Asphalt Membrane Waterproofing Materials

19.2.1.1. Asphalt
Asphalt for waterproofing shall conform to the Specification for Asphalt for Dampproofing and Waterproofing, ASTM D 449. Type I shall be used below ground and Type II used above ground.

19.2.1.2. Primer
The material used as primer shall conform to the Specification for Asphalt for Dampproofing and Waterproofing, ASTM D41.

19.2.1.3. Fabric
The fabric shall conform to either the Specification for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing, ASTM D 173, or the Specifications for Woven Glass Fabric Treated with Asphalt, ASTM D3515.

The fabric shall be stored in a dry, protected place. The rolls shall not be stored on end.

19.2.2. Preformed Membrane Waterproofing Systems

19.2.2.1. Primer
Primer for use with the rubberized asphalt membrane shall be a neoprene-based material, and the primer for use with the modified bitumen membrane shall be a resin-
or solvent-based material. Primers shall be of a type recommended by the Manufacturer.

19.2.2. Preformed Membrane Sheet

Preformed membrane sheet shall be of either the rubberized asphalt type or the modified bitumen type. The rubberized asphalt type shall consist of a rubberized asphalt sheet reinforced with a polyethylene film or mesh. The modified bitumen sheet type shall consist of a polymer modified bitumen sheet reinforced with a stitch-bonded polyester fabric or a fiberglass mesh. The membrane sheet shall conform to the following requirements in Table 19.1 and Table 19.2.

Table 19.1: Preformed Membrane Sheet for Bridge Deck Surfaces

<table>
<thead>
<tr>
<th>Property</th>
<th>Test</th>
<th>Value</th>
<th>Rubberized Asphalt Type</th>
<th>Modified Bitumen Type</th>
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<tr>
<td>Tensile Strength in Machine Direction</td>
<td>ASTM D 882</td>
<td>8.8 N/mm</td>
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<tr>
<td>% Elongation at break in Machine Direction</td>
<td>ASTM D 882</td>
<td>15% at 23°C±2°C</td>
<td>10% at 23°C± 2°C</td>
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<tr>
<td>Pliability</td>
<td>ASTM D 146</td>
<td>No cracks</td>
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<tr>
<td>Thickness, minimum</td>
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<td>1651 µm</td>
<td>1778 µm</td>
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<td>Softening Point, minimum</td>
<td>ASTM D 36</td>
<td>74°C</td>
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Table 19.2: Preformed Membrane Sheet for Surfaces Other Than Bridge Decks

<table>
<thead>
<tr>
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<th>Test</th>
<th>Value</th>
<th>Rubberized Asphalt Type</th>
<th>Modified Bitumen Type</th>
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<tr>
<td>Tensile Strength in Machine Direction</td>
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<td>3.5 N/mm</td>
<td>3.5 N/mm</td>
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<tr>
<td>% Elongation at break in Machine Direction</td>
<td>ASTM D 882</td>
<td>150% at 23°C± 2°C</td>
<td>25% at 23°C± 2°C</td>
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<tr>
<td>Pliability</td>
<td>ASTM D 146</td>
<td>No cracks</td>
<td>No cracks</td>
<td></td>
</tr>
<tr>
<td>Thickness, minimum</td>
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<td>1524 µm</td>
<td>1524 µm</td>
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<tr>
<td>Softening Point, minimum</td>
<td>ASTM D 36</td>
<td>74°C</td>
<td>99°C</td>
<td></td>
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</table>
ASTM D 882 shall be based on a Method A, 25 mm wide strip with 100 mm minimum initial grip separation and 100 mm gauge length at 50 mm per minute. The acceptance criterion shall be based on an average of five samples.

ASTM D 146 shall be based on a 180° bend over a 100 mm mandrel\textsuperscript{1} at -12°C.

19.2.2.3. Mastic

The mastic for use with preformed rubberized sheets shall be a rubberized asphalt cold-applied joint sealant. The mastic for use with modified bitumen sheet shall be a blend of bituminous and synthetic resins.

19.2.3. Waterproofing Admixtures in Concrete

Concrete made with waterproofing admixtures shall have a percent absorption after immersion and boiling of less than 5 percent at seven days and a volume of permeable voids less than 11 percent at seven days per ASTM C 642. The Contractor shall submit evidence in the form of test results showing compliance with these specifications, when they submit their concrete mix design.

If the concrete requires air entrainment, the Contractor shall also submit evidence to the Engineer that the admixture will not adversely affect the air void system of the hardened concrete. Test results complying with ASTM C 457 shall be provided as evidence to satisfy this requirement.

19.2.4. Miscellaneous Materials

1. Primers, fillers, sealers, joint tapes, adhesives, flashings, cant strips, and accessories shall be as recommended by the manufacturer of the primary protective barrier materials, for the intended application.

19.2.5. Protective Covers

Materials for protective covers shall conform to the following unless another type is specified in the contract documents.

For surfaces against which backfill will be placed, the protective cover shall consist of 3 mm hardboard or other material that shall provide equivalent protection from damage due to sharp coarse backfill material or from construction equipment.

For roadway surfaces of bridge decks, the protective cover shall consist of a layer of special asphalt concrete as specified in the contract documents.

For horizontal surfaces above which reinforced concrete structures are to be constructed, the protective cover shall consist of a 50 mm course of concrete mortar conforming to the requirements in Article \textsuperscript{10.16}, "Mortar and Grout" in Section 10, "Concrete Structures" except that the proportions shall consist of one part portland cement to three parts of fine aggregate. This mortar course shall be reinforced midway between its top and bottom surfaces with 150×150-MW9×MW9 welded wire fabric, or its equivalent.

19.2.5.1. Portland Cement Mortar

Mortar and Material to be used in mortar shall conform to the following below:

---

\textsuperscript{1} Mandrel: A metal rod or bar around which material, such as metal or glass, may be shaped.
1. Cement
   Cement shall conform to Article 10.4.1, "Cements" in Section 10, "Concrete Structures".

2. Fine aggregate
   Fine aggregate shall conform to Article 10.4.2.1, "Fine Aggregates" in Section 10, "Concrete Structures".

3. Lime
   Lime shall conform to ASTM C 207, type S or SA. Type N or NA, if tests show it not to be detrimental to mortar soundness.

4. Water
   Water shall confirm to Article 10.4.4, "Water" in Section 10, "Concrete Structures".

19.2.6. Dampproofing
   The primer and asphalt used for dampproofing shall conform to that specified in Article 19.3.4, "Asphalt Membrane Waterproofing System."

19.2.7. Inspection and Delivery
   All waterproofing and dampproofing materials shall be tested before shipment. Unless otherwise ordered by the Engineer, they shall be tested at the place of manufacture, and, when so tested, a copy of the test results shall be sent to the Engineer by the chemist or inspection bureau that has been designated to make the tests, and each package shall have affixed to it a label, seal, or other mark of identification, showing that it has been tested and found acceptable, and identifying the package with the laboratory tests.

   Factory inspection is preferred but, in lieu thereof, the Engineer may order that representative samples, properly identified, be sent to the Engineer for testing prior to shipment of the materials. After delivery of the materials, representative check samples shall be taken that shall determine the acceptability of the materials.

   All materials shall be delivered to the work in original containers, plainly marked with the Manufacturer's brand or label.

19.3. Construction Requirements

19.3.1. General
   Waterproofing shall not be applied to any surface until the Contractor has prepared to follow its application with the placing of the protective covering and backfill within a sufficiently short time so that the membrane will not be damaged by workers or equipment, exposure to weathering, or from any other cause. Damaged membrane or protective covering shall be repaired or replaced at the expense of the Contractor.

   Care shall be taken to confine all materials to the areas to be waterproofed or dampproofed and to prevent disfigurement of any other parts of the structure by dripping or spreading of the primer or asphalt.
19.3.2. Storage of Fabric

The fabric shall be stored in a dray, protected place. Rolls shall not be stored standing on end.

19.3.3. Preparation of Surface

All concrete surfaces to be waterproofed or dampproofed shall be reasonably smooth and free of foreign material that would prevent bond and of projections or holes which might cause puncture of the membrane or dampproofing. The surface shall be dry and, immediately before the application of the primer, the surface shall be thoroughly cleaned of dust and loose materials.

No waterproofing or dampproofing shall be done in wet weather, nor when the surface temperature is either below two degree Celsius (2°C) or below that recommended by the Manufacturer, unless approved by the Engineer in advance of the work. Should the surface of the concrete become temporarily damp, it shall be covered with a 50 mm layer of hot sand, which shall be allowed to remain in place from one to two hours, or long enough to produce a warm and surface-dried condition, after which the sand shall be swept back, uncovering sufficient surface for beginning work, and the operation repeated as the work progresses.

19.3.4. Application of Waterproofing and Dampproofing

19.3.4.1. Asphalt Membrane Waterproofing

Asphalt membrane waterproofing shall consist of a coat of primer applied to the prepared surface and a firmly bonded membrane composed of two layers of saturated fabric and three moppings of waterproofing asphalt and, when required, a protective cover.

1. Installation

Asphalt shall be heated to a temperature between one hundred and fifty degree Celsius (150°C) and one hundred and seventy five degree Celsius (175°C). The heating kettles shall be equipped with thermometers.

In all cases, the waterproofing shall begin at the low point of the surface to be waterproofed, so that water will run over and not against or along the laps.

The first strip of fabric shall be of half-width; the second shall be full-width, lapped the full-width of the first sheet; and the third and each succeeding strip shall be full width and lapped so that there will be two layers of fabric at all points with laps not less than 50 mm wide. All end laps shall be at least 300 mm.

Beginning at the low point of the surface to be waterproofed, a coating of primer shall be applied and allowed to dry before the first coat of asphalt is applied. The waterproofing shall then be applied as follows. Beginning at the low point of the surface to be waterproofed, a section about 500 mm wide and the full-length of the surface shall be mopped with the hot asphalt, and there shall be rolled into it, immediately following the mopping, the first strip of fabric, of half width, which shall be carefully pressed into place so as to eliminate all air bubbles and obtain close conformity with the surface. This strip and an adjacent section of the surface of a width equal to slightly more than half of the width of the fabric being used shall then be mopped with hot asphalt, and a full width of the fabric shall be rolled into this, completely covering the first strip, and pressed into place as before. This second strip and an adjacent section of the concrete surface shall then be mopped with hot asphalt.
and the third strip of fabric "shingled" on so as to lap the first strip not less than 50 mm. This process shall be continued with each strip of fabric lapping at least 50 mm over the second previous strip so that the entire surface is covered with at least two layers of fabric. The entire surface shall then be given a final mopping of hot asphalt.

The completed waterproofing shall be a firmly bonded membrane composed of two layers of fabric and three moppings of asphalt, together with a coating of primer. Under no circumstances shall one layer of fabric touch another layer at any point or touch the surface, as there must be at least three complete moppings of asphalt.

In all cases, the mopping on concrete shall cover the surface so that no gray spots appear, and on cloth it shall be sufficiently heavy to completely conceal the weave. On horizontal surfaces not less than 5 liters/m² of asphalt shall be used for finished work, and on vertical surfaces, not less than 6.25 liters/m² shall be used. The work shall be so regulated that, at the close of a day's work, all cloth that is laid shall have received the final mopping of asphalt. Special care shall be taken at all laps to see that they are thoroughly sealed.

2. Special Details

At the edges of the membrane and at any points where it is punctured by such appurtenances as drains or pipes, suitable provisions shall be made to prevent water from getting between the waterproofing and the waterproofed surface.

All flashing at curbs and against girders, spandrel walls, etc, shall be done with separate sheets lapping the main membrane not less than 300 mm. Flashing shall be closely sealed either with a metal counter-flashing or by embedding the upper edges of the flashing in a groove poured full of joint filler.

Joints that are essentially open joints, but that are not designed to provide for expansion, shall first be caulked with oakum or other material approved by the Engineer, and then filled with hot joint filler.

Expansion joints, both horizontal and vertical, shall be provided with sheet copper or lead in "U" or "V" form in accordance with the contract documents. After the membrane has been placed, the joint shall be filled with hot joint filler. The membrane shall be carried continuously across all expansion joints.

At the ends of the structure, the membrane shall be carried well down on the abutments and suitable provision made for all movement.

3. Damage Patching

Care shall be taken to prevent damage to the finished membrane by the passage over it of workers or equipment, or by throwing any material on it. Any damage which may occur shall be repaired by patching. Patches shall extend at least 300 mm beyond the outermost damaged portion, and the second ply shall extend at least 75 mm beyond the first.

19.3.4.2. Preformed Membrane Waterproofing Systems

Preformed membrane waterproofing systems shall consist of a primer applied to the prepared surface, a single layer of adhering preformed membrane sheet and, when required, a protective cover.
1. Installation on Bridge Decks

Prior to applying the primer, an oil-resistant construction paper mask shall be taped or held with an adhesive to any deck areas that will later be covered by expansion dams or headers.

Membrane and asphaltic concrete overlays involves a waterproofing membrane covered with one or two courses of asphaltic concretes. The economics of asphalt when available may make this a good option for using the good riding quality and shock-absorbing qualities of the material. Membranes are not recommended for repairing badly delaminated decks with corroded reinforcing bars close to the surface. There are many types of membranes, including hot-applied, rubberized membranes; sheet membranes; and liquid-applied, polymer membranes. The membranes should be capable of bonding to concrete, bridging cracks, waterproofing, and bonding to AC (asphalt cements) overlays without being affected by one hundred and forty nine degree Celsius (149°C) asphalt. Some membranes require protection boards and two passes of asphaltic concrete in order to minimize damage during compaction, and these systems may not be suitable for repair of existing bridges that were not designed for the extra dead load. Some sheet membranes may not bond well to concrete, or may debond at later dates if exposed to heat and sunlight, which creates vapor pressure and weakened bond due to temperature. Liquid-applied membranes may require special expertise. Some jurisdictions require warranties on membrane installation.

The membrane seal and asphalt concrete shall be placed continuously across such paper masks; however, the mask and the preformed sheet shall be cut at or near the expansion joint when ordered by the Engineer.

The neoprene-based primer shall be applied in one coat at a rate of approximately 7.4 m²/liter. The resin- or solvent-based primer shall be applied in one coat at a rate 3.0 m²/liter approximately. Primer shall be applied by spray or squeegee methods to the entire area to be sealed.

All primers shall be thoroughly mixed and continuously agitated during application. Primers shall be allowed to dry to a tack-free condition before placing membrane sheets.

Should membrane sheets not be placed over solvent based primed surfaces within 24 hours, or neoprene-based primed surfaces within 36 hours, or resin-based primed surfaces within 8 hours, the surfaces shall be re-primed.

The preformed membrane sheets shall be applied to the primed surfaces either by hand methods or by mechanical applicators. The membrane sheet shall be placed in such a manner that a shingling effect is achieved in the direction that water will drain. First, a 300 mm minimum width membrane strip shall be placed along the juncture of deck and base of barrier railing or curb face at the low side of the deck with the sheet extending up the face 75 mm. Next, starting at the gutter line, sheets shall be laid longitudinally and side lapped with adjacent sheets by not less than 60 mm and end lapped by not less than 150 mm. A 300 mm minimum width strip shall then be placed at the juncture of deck and base of curb or railings at the high side of the deck extending up the face 75 mm. After being laid, the membrane sheets shall be rolled with hand rollers or other apparatus as necessary to develop a firm and uniform bond with the primed concrete surfaces. Procedures shall be used that minimize wrinkles and air bubbles. Any tears, cuts, or narrow overlaps shall be patched, using a satisfactory adhesive and by placing sections of membrane sheet over the defective area in such a manner that the patch extends at least 150 mm beyond the defect. On modified bitumen
sheets with a permanent polyester film, a propane torch shall be used to melt the polyester film on the section to be patched. The patch shall then be placed over the heated surface. All patches shall be rolled or pressed firmly onto the surface.

At all open joints, at deck bleeder pipes, and at other locations when ordered by the Engineer, the membrane sheet shall be cut and turned into the joint or bleeder as the membrane sheet is laid.

For rubberized asphalt sheets and modified bitumen sheets, mastic shall be applied as a bead along the exposed edge of the membrane sheet that extends up the barrier railing or curb face, and that terminates in the high-side gutter after the sheets have been installed.

2. Installation on Other Surfaces

Installation of preformed membranes on surfaces other than bridge decks shall conform to the applicable requirements for bridge decks and to the following:

- Preformed membrane material shall be placed vertically with each successive sheet lapped to the preceding by a minimum of 75 mm. Horizontal splices shall be lapped by a minimum of 150 mm.
- Exposed edges of membrane sheets shall have a troweled bead of Manufacturer’s recommended mastic or sealing tape applied after the membrane is placed.
- All projecting pipe, conduits, sleeves, or other facilities passing through the preformed membrane waterproofing shall be flashed with prefabricated or field-fabricated boots, fitted coverings, or other devices as necessary to provide watertight construction.

19.3.4.3. Dampproofing

Concrete, brick, or other surfaces to be protected by dampproofing shall be thoroughly cleaned before the primer is applied. The surface to be dampproofed shall be primed and then thoroughly mopped with waterproofing asphalt. When the first mopping of asphalt has set sufficiently, the entire surface shall be mopped with the second coating of hot asphalt. Special care shall be taken to see that there are no skips in the coatings and that all surfaces are thoroughly covered.

19.3.5. Protective Covers

Protective covers shall be installed sufficiently soon after the application of waterproofing to prevent any damage to the waterproofing from exposure to sunlight or the weather or damage from traffic or subsequent construction operations.

Hardboard protective covering shall be placed on a coating of adhesive of a type recommended by the waterproofing Manufacturer. The adhesive shall be applied at a rate sufficient to hold the protective covering in position until the backfill is placed.

19.4. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and this section requirements. For work acceptance, Contractor shall apply quality control for waterproofing work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.
19.4.1. Quality Control
All waterproofing works and materials should be controlled and inspected to insure that the work is according to the requirements of materials mentioned in the article [19.2] and Table 19.5.

The proofing materials should be tested according to article [19.2.7] "Inspection and Delivery".

For work acceptance the installation work procedure should be inspected to insure that is according to the installation requirements mentioned in the article [19.3] including the surface preparation.

19.4.2. Quality Assurance
Ministry, at any time, has the right to insure the quality of work, that are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that insure the quality of all works that was finished according to the required tests mentioned in the related sections and the manufacturer requirements.

19.5. Measurement and Payment

19.5.1. Measurement
Waterproofing and dampproofing will be measured by the square meter complete in place and accepted.

19.5.2. Payment
Payment will be made on the basis of the number of square meters of waterproofing or dampproofing measured.

Payment for waterproofing includes full compensation for the cost of providing all equipment, materials, and labor necessary for the satisfactory completion of the waterproofing membrane and the protection cover.

Payment for dampproofing includes full compensation for the cost of providing all equipment, materials, and labor necessary for the satisfactory completion of the dampproofing.

Payment will be made as indicated in Table 19.3. And quality control requirements for waterproofing are shown in Table 19.4.

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<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
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<td>Waterproofing</td>
<td>Square Meter</td>
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### Section 19: Waterproofing

**Table 19.4: Quality Control Requirements For Waterproofing**

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
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<tbody>
<tr>
<td>Application</td>
<td>Surface preparation</td>
<td>Visual inspection</td>
<td>In situ</td>
<td>---------</td>
<td>Article 19.3.23</td>
</tr>
<tr>
<td></td>
<td>Installation on bridge decks</td>
<td>Visual inspection</td>
<td>In situ</td>
<td>---------</td>
<td>Article 19.3.4.1</td>
</tr>
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</table>

**Table 19.5: AASHTO and ASTM Designation and its Title**

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>as specified</td>
<td></td>
<td>ASTM D 449</td>
<td>Standard Specification for Asphalt Used in Dampproofing and Waterproofing</td>
</tr>
<tr>
<td>as specified</td>
<td></td>
<td>ASTM D 41</td>
<td>Standard Specification for Asphalt Primer Used in Roofing, Dampproofing, and Waterproofing</td>
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<tr>
<td>as specified</td>
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<td>ASTM D 173</td>
<td>Standard Specification for Bitumen-Saturated Cotton Fabrics Used in Roofing and Waterproofing</td>
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<tr>
<td>see table 19.1</td>
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<td>ASTM D 882</td>
<td>Standard Test Method for Tensile Properties of Thin Plastic Sheeting</td>
</tr>
<tr>
<td>and table 19.2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>see table 19.1</td>
<td></td>
<td>ASTM D 146</td>
<td>Standard Test Methods for Sampling and Testing Bitumen-Saturated Felts and Woven Fabrics for Roofing and Waterproofing</td>
</tr>
<tr>
<td>and table 19.2</td>
<td></td>
<td></td>
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<tr>
<td>see table 19.1</td>
<td></td>
<td>ASTM D 36</td>
<td>Standard Test Method for Softening Point of Bitumen (Ring-and-Ball Apparatus)</td>
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<tr>
<td>and table 19.2</td>
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<td></td>
</tr>
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<td>percent absorption after immersion and boiling of less than 5 percent at seven days and a volume of permeable voids less than 11 percent at seven days</td>
<td>ASTM C 642</td>
<td>Standard Test Method for Density, Absorption, and Voids in Hardened Concrete</td>
<td></td>
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<tr>
<td>as specified</td>
<td>ASTM C 457</td>
<td>Standard Test Method for Microscopical Determination of Parameters of the Air-Void System in Hardened Concrete</td>
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<tr>
<td>as specified</td>
<td>ASTM C 207</td>
<td>Standard Specification for Hydrated Lime for Masonry Purposes</td>
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</tbody>
</table>

### 19.6. References

"AASHTO LRFD Bridges Construction Specifications"-2004- Sec. 21

FHWA: "Standard Specifications For Construction of Roads and Bridges on Federal Highway Projects"-FP-03.

Washington Standard Specifications for Road, Bridge, and Municipal Construction 2008 M 41-10 Sec. 9-23.8

MOT Specifications "Ministry of Transportation- Saudi Arabia Kingdom" Sec. 5.12.

SECTION 20. DRAINAGE SYSTEMS

20.1. Description
This work shall consist of furnishing and installing gully and channel grates and frames on bridge deck, subways and underpasses for collecting surface water from structures and draining pipes and down-pipes which are connected to the gully and channel grates by hoppers. The gully and channel grates and frames may be of cast iron or cast steel with or without integral cast hoppers. In the absence of integral cast hoppers, fabricated U-PVC or GRP hoppers will be necessary.

This work shall also consist of furnishing and installing of concrete gutters, weep holes, drainage blankets and geocomposite drainage systems for all earth retaining systems.

The Contractor shall submit, as early as possible, details of all drainage material and components he proposes to use for the approval of the Engineer. No material or component shall be incorporated in the works without written approval of the Engineer.

20.1.1. Definitions

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>Gully</td>
<td>Small valley or ravine serving as a drainageway after prolonged heavy rains.</td>
</tr>
<tr>
<td>Gutter</td>
<td>A channel along the eaves or on the roof; collects and carries away rainwater.</td>
</tr>
<tr>
<td>Hopper</td>
<td>Funnel-shaped receptacle; contents pass by gravity into a receptacle below.</td>
</tr>
<tr>
<td>Scupper</td>
<td>Opening for draining water from the bridge deck.</td>
</tr>
<tr>
<td>Weep hole</td>
<td>A small opening, the purpose of which is to permit drainage of water that accumulates behind a retaining wall.</td>
</tr>
</tbody>
</table>

20.2. Materials

20.2.1. Materials Related to Superstructure

20.2.1.1. Gully and Channel Grates and Frames

Gully and channel grates and frames shall conform to the requirements of Saudi Arabian Standards. Alternatively, drainage gullies shall be of heavy duty design of the type(s) indicated on the plans, made of structural steel or gray cast iron to conform with AASHTO M105, Class No 25 S, or equivalent.

Integral cast hoppers shall be of the same grade and quality as the gully or channel grate and frame. Fabricated U-PVC or GRP shall be to the approval of the Engineer who may require material and load testing before giving approval.

20.2.1.2. Fiberglass Pipe

Fiberglass pipe and fittings shall conform to ASTM D 2996 Designation Code RTRP-11AE-5112. Pipe and fittings with Class C or Class F liners are acceptable. The finish color shall be concrete gray.
20.2.1.3. PVC and U-PVC Pipes

Pipes of synthetic material for general drainage use shall be approved pipes of polythene, polypropylene, or polyvinylchloride. Unplasticized polyvinylchloride pipes shall conform to the requirements of Class 2 and 3 ASTM D3333, PVC pipes and sleeves shall comply with SASO14, and fittings shall comply with ISO/DIN 4422, 10 bars class.

20.2.1.4. Aluminum Pipes

Aluminum pipes, sleeves and fittings shall conform to ASTM B211, alloy 6061-T6.

20.2.1.5. Steel Alloy Pipe for Bridge Storm Drains

Steel alloy pipe and fittings shall be of alloy steel conforming to the chemical analysis of ASTM A 53M, Grade B or ASTM A 500. Ductile iron pipe conforming to ASTM A 377 (ANSI/AWWA C151/A21.51) may be furnished as an alternate. The pipe and fittings for both the steel alloy pipe and ductile iron pipe alternate shall be zinc-coated (galvanized) according to ASTM A 123M. Steel pipe and fitting shall be connected by welding before galvanizing.

Ductile iron pipe fittings shall conform to ASTM A 48, Class 30. Pipe bends shall be of the long radius type. Pipe joints shall be formed using groove-type couplings consisting of a housing clamp keyed into a groove cut around the full pipe circumference. A gasket of molded or extruded butyl or EPDM (ethylene propylene diene M-class rubber) shall be provided to create a sealed joint. Bolts shall be of track type conforming to ASTM A 183 with oval necks and heavy hexagon standard nuts. The assembly shall be galvanized according to Article 13.3.7, “Galvanizing” in these specifications.

20.2.1.6. Zinc Coating on Steel

Zinc coating (hot-dip galvanizing) applied on iron and steel products shall conform to Article 13.3.7 in Section 13, “Steel Structures” in these specifications.

20.2.1.7. Castings, Materials and Components for Drainage Structures

All inlet and manhole castings, grates, extension rings, extension frames, and covers, shall be capable of withstanding HL-93 live load vehicle when tested as a complete. These materials shall conform to the following:

1. Gray iron castings shall conform to AASHTO M 105 and AASHTO M 306 for Class 30B and Class 35B and shall be true to pattern in form and dimensions, free from pouring faults, sponginess, cracks, blowholes, and other defects in composition affecting their strength and value for the service intended.
2. The castings shall be sandblasted or otherwise effectively cleaned of scale and sand so as to present a smooth, clean, and uniform surface.
3. Carbon steel extension frames and rings for inlets and manholes shall be galvanized according to AASHTO M 111 when specified. Welding of fabricated steel shapes and structures shall conform to AWS D1.1. No punching, drilling, reaming, welding, or cutting will be allowed in the field. Any damage to the galvanized coating during and prior to installation shall be repaired without additional compensation.
4. Structural steel shapes used in the fabrication of drainage structures and components shall conform to Article 13.3.5, “Steel Casting” in theses specifications.
5. Ductile iron castings shall conform to ASTM A 536, Grade 65-45-12 or Grade 80-55-06.

20.2.2. Materials Related to Retaining Systems

20.2.2.1. Pipe and Perforated Pipe


20.2.2.2. Filter fabric


Filter fabric shall prevent clogging of the drain and transmission of fines from the backfill.

20.2.2.3. Permeable Material


20.2.2.4. Geocomposite Drainage Systems

Geocomposite drainage systems shall conform to the requirements specified in the contract documents or the approved working drawings.

20.3. Construction Requirements

Drainage facilities shall be constructed in accordance with the details shown on the approved working drawings or in the contract documents, and these specifications.

20.3.1. Inlet Frames, Grates, and Scuppers

The bearing surfaces of frames and grates shall be machined so that the grates have uniform bearing on the frames. They shall be match marked before being delivered. Inlet frames, grates, and scuppers if fabricated from steel shall be zinc-coated.

20.3.2. Steel Alloy Pipe

Areas where galvanizing has been damaged shall be repaired by any of the three methods specified in ASTM A 780. In all cases, the repair shall achieve the minimum coating thickness specified for the item. The type of threaded concrete inserts for support brackets and clamp shall be approved.

20.3.3. Fiberglass Pipe and Fittings

Fiberglass pipe and fittings may be substituted where steel alloy pipe is specified.

Runs of pipe shall be supported at spacings not exceeding those recommended by the manufacturer of the pipe. Supports that have point contact or narrow supporting areas shall be avoided. Standard sling, clamp, and clevis hangers and shoe supports designed for use with steel pipe may be used. A minimum strap width for hangers shall be 37 mm for 150 mm diameter pipe and 50 mm for 300 mm diameter pipe. Straps shall have 120 degrees contact with the pipe. Pipe supported on surface with less than
Section 20: Drainage Systems  Construction Requirements

120 degrees contact shall have a split fiberglass pipe protective sleeve bonded in place with adhesive.

All fiberglass pipe and fittings shall be pigmented resin throughout the wall. Color to be standard concrete gray or designated color. Painted gel-coat or exterior coating will not be acceptable. Fiberglass pipe and fittings shall be handled and installed according to the manufacturer’s recommendations.

20.3.4. Concrete Gutters

Concrete gutters shall be constructed to the profile indicated in the contract documents or on the approved working drawings. Pneumatically applied mortar shall conform to the requirements of Section 23, "Pneumatically Applied Mortar". Outlet working shall be provided at sags in the profile at the low ends of the gutter, and at other indicated locations.

20.3.5. Weep Holes

Weep holes, if specified, shall be constructed at the locations shown in the contract documents or on the approved working drawings. A minimum of 0.06 cubic meter of permeable material encapsulated with filter fabric shall be placed at each weep hole.

Joints between precast concrete retaining wall face panels which function as weep holes shall be covered with filter fabric. The filter fabric shall be bonded to the face panels with adhesive conforming to Federal Specification MMM-A-121. The face panels which are to receive the filter fabric shall be dry and thoroughly cleaned of dust and loose material.

20.3.6. Drainage Blankets

Drainage blankets consisting of permeable material encapsulated in filter fabric, collector pipes, outlet pipes and clean out pipes shall be constructed as specified in the contract documents or on the approved working drawings.

The subgrade to receive the filter fabric shall conform to the compaction and elevation tolerance specified and shall be free of loose or extraneous material and sharp objects that may damage the filter fabric during installation. The filter fabric shall be stretched, aligned, and placed in a wrinkle-free manner. Adjacent borders of the filter fabric shall be overlapped from 300 mm to 450 mm. Should the filter fabric be damaged, the torn or punctured section shall be repaired by placing a piece of filter fabric that is large enough to cover the damaged area and to meet the overlap requirement.

The permeable material shall be placed in horizontal layers and thoroughly consolidated along with and by the same methods specified for structure backfill. Ponding and jetting of permeable material or structure backfill material adjacent to permeable material will not be permitted. During spreading and compaction of the permeable material and structural backfill or embankment material, a minimum of 150 mm of such material shall be maintained between the filter fabric and the contractor's equipment.

The perforated collector pipe shall be placed within the permeable material to the flow line elevations shown.

Outlet pipes shall be placed at sags in the flow line, at the low end of the collector pipe, and at other locations shown or specified in the contract documents. Rock slope protection, when required at the end of outlet pipes, shall conform to the details in the
contract documents or approved working drawings and the requirements in Section 21, "Slope Protection".

Cleanout pipes shall be placed at the high ends of collector pipes and at other locations as specified in the contract documents.

20.3.7. Geocomposite Drainage Systems

Geocomposite drainage systems shall be installed at the locations shown in the contract documents or on the approved working drawings. The geocomposite drainage material shall be placed and secured tightly against the excavated face, lagging or back of wall as specified in the contract documents. When concrete is to be placed against geocomposite drainage materials, the drainage material shall be protected against physical damage and grout leakage.

20.4. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and this section requirements. For work acceptance, Contractor shall apply quality control for drainage system work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.

20.4.1. Quality Control

All drainage system works and materials should be controlled and inspected to insure that the all drainage system elements work is according to the requirements of materials mentioned in the article 20.2 and Table 20.3.

For work acceptance the installation work procedure should be inspected to insure that is according to the installation requirements mentioned in the article 20.3 for all components of the drainage system.

20.4.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of work, that are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that insure the quality of all works that was finished according to the requirements mentioned in the Table 20.2.

20.5. Measurement and Payment

20.5.1. Measurement

20.5.1.1. Gully Grates and Frames.

Gully grates and frames shall be measured by the number of units installed, completed and accepted. Hoppers connecting the gully frames to drainage pipes shall not be measured separately but shall be considered subsidiary to gully grates and frames.

20.5.1.2. Bridge Deck Drainage Pipes

Bridge deck drainage pipes which are part of the bridge deck drainage system shall be measured by the linear meter of the total length of pipes installed, completed and
accepted. No separate measurement will be made for pipes cast into concrete or for pipes connecting fully the channel frames to drainage pipes or for pipe supports and joints or for discharge hoppers from drainage pipes to down-pipes, but shall be considered subsidiary to drainage pipes.

20.5.1.3. Subsidiary Work
No measurement will be made for testing of gully grates and frames or for pipe supports or for testing of drainage pipes as these are subsidiary work to the items listed in Article 20.5.2, “Payment”.

20.5.2. Payment
Full compensation for revisions to drainage system, or other facilities made necessary by the use of an alternative earth retaining systems shall be considered as included in the contract price paid per square meter for earth retaining systems and therefore adjustment to the compensation will be made.

Payment will be made as indicated in Table 20.1. And the quality control requirements for drainage systems are shown in Table 20.2.

Table 20.1: Drainage Systems Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.2.1.1</td>
<td>Gully and Channel Grates and Frames</td>
<td>Each</td>
</tr>
<tr>
<td>20.2.1.2</td>
<td>Fiberglass Pipe</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>20.2.1.3</td>
<td>PVC and U-PVC Pipes</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>20.2.1.4</td>
<td>Aluminum Pipes</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>20.2.1.5</td>
<td>Steel Alloy Pipe for Bridge Storm Drains</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>20.2.1.6</td>
<td>Zinc Coating on Steel</td>
<td>Lump sum</td>
</tr>
<tr>
<td>20.2.1.7</td>
<td>Inlet and Manhole Castings, Grates, Extension Rings, Extension Frames, and Covers</td>
<td>Each</td>
</tr>
<tr>
<td>20.2.2.1</td>
<td>Pipe and Perforated Pipe</td>
<td>Linear Meter</td>
</tr>
<tr>
<td>20.2.2.2</td>
<td>Filter fabric</td>
<td>Square Meter</td>
</tr>
<tr>
<td>20.2.2.3</td>
<td>Permeable Material</td>
<td>Square Meter</td>
</tr>
<tr>
<td>20.2.2.4</td>
<td>Geo-composite Drainage Systems</td>
<td>Square Meter</td>
</tr>
</tbody>
</table>
### Table 20.2: Quality Control Requirements For Drainage Systems

<table>
<thead>
<tr>
<th>Work Description</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geocomposite drainage systems</td>
<td>Surveying and inspection</td>
<td>In situ</td>
<td>--</td>
<td>Article 20.3.7</td>
</tr>
<tr>
<td>Bridge deck drainage pipes</td>
<td>Drainage quality assurance</td>
<td>In situ</td>
<td>--</td>
<td>Article 20.3</td>
</tr>
</tbody>
</table>

### Table 20.3: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>as specified</td>
<td>AASHTO M105</td>
<td></td>
<td>Standard Specification for Gray Iron Castings</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM D3333</td>
<td></td>
<td>Standard Practice for Sampling Manufactured Staple Fibers, Sliver, or Tow for Testing</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM D 2996</td>
<td></td>
<td>Standard Specification for Filament-Wound &quot;Fiberglass&quot; (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM B211</td>
<td></td>
<td>Standard Specification for Aluminum and Aluminum-Alloy Bar, Rod, and Wire</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM A 53M</td>
<td></td>
<td>Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM A 377</td>
<td></td>
<td>Standard Index of Specifications for Ductile-Iron Pressure Pipe</td>
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<tr>
<td>as specified</td>
<td>ASTM A 48</td>
<td></td>
<td>Standard Specification for Gray Iron Castings</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM A 183</td>
<td></td>
<td>Standard Specification for Carbon Steel Track Bolts and Nuts</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 306</td>
<td></td>
<td>Standard Specification for Drainage, Sewer, Utility, and Related Castings</td>
</tr>
</tbody>
</table>
### 20.6. References


OKLAHOMA. “Oklahoma Department of Transportation Standard Specifications for Highway Construction”-1999- Sec. 510.


MOT KSA;"General Specifications For Road And Bridge Construction"- November 1998-Sec. 5.11.

<table>
<thead>
<tr>
<th>as specified</th>
<th>AASHTO M 111</th>
<th>Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>as specified</td>
<td>ASTM A 780</td>
<td>Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings</td>
</tr>
</tbody>
</table>
SECTION 21. SLOPE PROTECTION

21.1. General

21.1.1. Description
   This work shall consist of the construction of bank and slope protection courses in accordance with these specifications and in reasonably close conformity with the lines, grades, and thicknesses shown in the contract documents or established by the Engineer. These provisions shall apply to riprap, and concrete slope paving.

21.1.2. Types
   Types of slope protection are designated as riprap, concrete slope paving, and precast concrete slope paving.

21.1.2.1. Riprap
   Riprap types can be classified as follows:
   - Hand-Placed Riprap: Hand-placed stones on earth or gravel bedding
   - Machine-Placed Riprap: Machine-placed stones on earth or gravel bedding
   - Wire-Enclosed Riprap (Gabions): Stones placed in wire fabric enclosures
   - Grouted Riprap: Hand-placed riprap as described above with voids filled with sand-cement grout
   - Sacked Concrete Riprap-Hand-placed sacked concrete.

21.1.2.2. Concrete Slope Paving
   Cast-in-Place Slope Paving-Portland cement concrete, pneumatically applied mortar or, when permitted, fabric forms filled with structural concrete grout.

21.1.2.3. Precast Concrete Slope Paving
   Portland cement concrete slabs, blocks, or shapes precast prior to placement

21.2. Working Drawings
   Whenever specified in the contract documents or requested by the Engineer, the Contractor shall provide working drawings with design calculations and supporting data in sufficient detail to permit a structural review of the proposed design of a slope protection system. When concrete is involved, such data shall include the sequence and rate of placement. Sufficient copies shall be furnished to meet the needs of the Engineer and other entities with review authority. The working drawings shall be submitted sufficiently in advance of proposed use to allow for their review; revision, if needed; and approval without delay to the work.

   The Contractor shall not start the construction of any slope protection system for which working drawings are required until the drawings have been approved by the Engineer. Such approval will not relieve the Contractor of responsibility for results obtained by use of these drawings or any other responsibilities under the contract documents.
21.3. Materials

21.3.1. Stone materials

The stone materials to be used for riprapping and protecting slopes shall be from hard rocks which are resistant to water and weather. They shall be free from cracks, clay, soluble, and fragile materials. They shall achieve, except otherwise indicated in the special specifications, the qualitative requirements shown in Table 21.1. The loose or grouted riprap shall fulfill the volumetric distribution requirements indicated in the special specifications and contract documents or one of the distributions listed in Table 21.2. The smallest dimension of the stone shall not be less than 1/3 of its maximum dimension. Materials shall be from angled stones to provide sufficient friction between stones.

Gabion works may use rounded stones and the size of the used stones shall range between 100-200 mm, their weight between 2-15 kg, and the percentage of stones with more than 5 kg in weight shall not be less than 50%.

<table>
<thead>
<tr>
<th>Table 21.1: Stone Materials Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Property</strong></td>
</tr>
<tr>
<td>Apparent density, kg/m$^3$, minimum</td>
</tr>
<tr>
<td>Absorption, %, maximum</td>
</tr>
<tr>
<td>Durability index for coarse materials, %, minimum</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 21.2: Volumetric distribution of riprap stone materials</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class</strong></td>
</tr>
<tr>
<td>I</td>
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<td>II</td>
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<tr>
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<tr>
<td>III</td>
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</tbody>
</table>

$^*$The volume of a stone with these cubic dimensions will have a mass approximately equal to the specified stone mass.

Contractor, before commencing work by a period not less than 15 days, shall choose stone material sources, conduct the necessary tests on them, and submit a technical report including sources, available and estimated quantities to the engineer for approval. Contractor shall obtain the permission for using those sources from their owners.
21.3.2. Wire-Enclosed Riprap (Gabions)

Gabions shall be constructed of wire mesh. The wire mesh shall be made of galvanized steel wire having a minimum size of (U.S. Wire Gage No. II) (3 mm diameter). The tensile strength of the wire shall be in the range of 415 to 585 MPa, determined in accordance with ASTM A 392. The minimum zinc coating of the wire shall be 0.25 kg/m$^2$ of uncoated wire surface, as determined in accordance with AASHTO T 65M/T 65 (ASTM A 90/ A 90M).

Selvage, tie, and connection wire shall meet the same strength and coating requirements specified above for wire used in the wire mesh.

21.3.3. Filter Fabric

Filter fabric shall meet the requirements of AASHTO M288, Class A or B.

21.3.4. Grout

Cement grout used for grouted stone riprap shall consist of sand, cement, and water mix in the ratio of 1 cement to 3 sand. It shall achieve requirements of specification ASTM C270 and the used cement shall be sulphate resistant type V or normal portland cement type I and compliant with requirements of the standard specification ASTM C150, unless otherwise specified in the special specifications. Cement shall be supplied from approved sources and with cement shipments shall be enclosed certificates of source guarantee duly approved and authenticated.

Water used in mixing shall be in compliance with the requirements of Article 10.4.4, “Water” of these specifications. The used sand shall be in compliance with requirements of specification AASHTO M 45, “Aggregate for Masonry Mortar”.

21.3.5. Sacked Concrete Riprap

Concrete for sacked concrete riprap shall consist of a mixture of clean pit run or washed sand and gravel, cement, and water. The mixture shall contain not less than 225 kg/m$^3$ of Portland cement and sufficient water to obtain a slump of 75 to 125 mm. Sacks for sacked concrete riprap shall be made of 0.34 kg/m$^2$ burlap or other fabric having equal or greater strength. Sacks shall be approximately 495mm×915 mm measured inside the seams when the sack is laid flat, with an approximate capacity of 0.035 m$^3$. Sound, reclaimed sacks may be used.

21.3.6. Portland Cement Concrete

Portland cement concrete for cast-in-place slope paving shall conform to the provisions in Section 10, "Concrete Structures", Article 10.3, "Classes of Concrete", for Class A concrete using the 25 mm maximum combined grading.

21.3.7. Expansion Joint filler

Expansion joint filler shall conform to the provisions in Article 10.11.2.1, "Premolded Expansion Joint Fillers".

21.3.8. Pneumatically Applied Mortar

Materials for pneumatically applied mortar shall conform to the requirements of Section 23, "Pneumatically Applied Mortar."
21.3.9. Precast Portland Cement Concrete Blocks and Shapes

Precast portland cement concrete blocks and shapes shall meet the requirements of ASTM C 129, C 139, or C 90 grade unless otherwise specified in the contract documents. Materials for precast Portland cement concrete slabs shall conform to the requirements in Article 10.15, "Precast Concrete Members."

21.3.10. Reinforcing Steel

Reinforcement shall conform to the provisions in Section 11, "Reinforcing Steel".

21.3.11. Geocomposite Drain

Geocomposite drain when specified shall consist of a manufactured core with one or both sides covered with a layer of filter fabric.

The manufactured core shall be a preformed grid of embossed plastic, a mat of random shapes of plastic fibers, a drainage net consisting of a uniform pattern of polymeric strands forming two sets of continuous flow channels, a system of plastic pillars and interconnections forming a semi-rigid mat, or other system approved by the Engineer that will conduct the flow of water designated in the contract documents.

Filter fabric shall conform to the requirements of Article 21.3.3, "Filter Fabric" and shall be integrally bonded to the core material.

The Contractor shall furnish to the Engineer a signed certification from the Manufacturer stating that the geocomposite drain proposed for use is capable of withstanding design loadings at all planned locations without appreciably decreasing the carrying capacity of the designed drainage voids for the entire height or length of the drain.

21.4. Construction

21.4.1. Preparation of Slopes

Where required, slopes shall be shaped to allow the full thickness of the specified slope protection and any bedding or filter gravel. Slopes shall not be steeper than the natural angle of repose of the slope protection material specified in the contract documents. Where the slopes cannot be excavated to undisturbed material, the underlying material shall be compacted to 95 percent (95%) standard density as specified in AASHTO T 99.

21.4.2. Bedding

When called for in the contract documents, a layer of filter gravel or filter fabric shall be placed on the slope immediately prior to placement of the riprap or slope paving. The layer of filter gravel shall be shaped to provide the minimum thickness specified in the contract documents.

21.4.3. Filter Fabric

When specified in the contract documents, filter fabric shall be spread uniformly over the prepared slope or surface. The fabric shall be unrolled directly on the surface to the lines and dimensions shown in the contract documents. The filter fabric shall be lapped a minimum of 300 mm in each direction and shall be anchored in position with approved anchoring devices. The Contractor shall place the riprap in a manner that will
not tear, puncture, or shift the fabric. Tracked or wheeled equipment shall not be permitted on the fabric covered slopes.

21.4.4. Geocomposite Drain

Geocomposite drains shall be installed at locations shown in the contract documents and where directed by the Engineer. Collection and discharge systems shall be installed as shown in the contract documents or as directed by the Engineer.

Core material manufactured from impermeable plastic sheeting having connecting corrugations shall be placed with the corrugations approximately perpendicular to the drainage collection system.

When only one side of the geocomposite drain is covered with filter fabric, the drain shall be installed with the filter fabric side facing the embankment. The fabric facing the embankment side shall overlap a minimum of 75 mm at all joints and wrap around the exterior edges a minimum of 75 mm beyond the exterior edge. If additional fabric is needed to provide overlap at joints and wrap-around at edges, the added fabric shall overlap the fabric on the geocomposite drain at least 150 mm and be attached thereto.

Should the fabric on the geocomposite drain be torn or punctured, the damaged section shall be replaced completely or repaired by placing a piece of fabric that is large enough to cover the damaged area and provide a 150 mm overlap all around the damaged area.

21.4.5. Hand-Placing Stones

Where hand-placing of stones is specified in the contract documents, the larger stones shall be placed first with close joints in the footing trench. Stones shall be placed with their longitudinal axis normal to the embankment face and arranged so that each stone above the foundation course has a three-point bearing on the underlying stones. Bearing on smaller stones that may be used for chinking voids shall not be acceptable. Placing of stones by dumping shall not be permitted. Interstices shall be filled with smaller stones and spalls.

21.4.6. Machine-Placed Stones

21.4.6.1. Dry Placement

Machine-placed stones shall be so placed so as to provide a minimum of voids, and the larger stones shall be placed in the toe course and on the outside surface of the slope protection. The stone may be placed by dumping and may be spread in layers by bulldozers or other suitable equipment. At the completion of slope protection work, the footing trench shall be filled with excavated material, and compaction will not be required.

21.4.6.2. Underwater Placement

When placed under water, free dumping shall not be permitted without written permission of the Engineer. Placement shall be by controlled methods using bottom dump buckets or wire rope baskets lowered through the water to the point of placement.
21.4.7. Wire-Enclosed Riprap (Gabions)

21.4.7.1. Fabrication

The wire mesh shall be twisted to form hexagonal openings of uniform size. The maximum linear dimension of the mesh opening shall not exceed 115 mm and the area of the mesh opening shall not exceed 5160 mm$^2$. The mesh shall be fabricated in such a manner as to be non raveling.

Gabions shall be fabricated so the sides, ends, lid, and diaphragms can be assembled at the construction site into rectangular baskets of the specified size. Gabions shall be of single-unit construction, i.e., base, lid, ends, and sides shall be either woven into a single unit, or one edge of these members connected to the base section of the gabion in a manner such that strength and flexibility at the point of connection is at least equal to that of the mesh.

Where the length of the gabion exceeds its horizontal width, the gabion shall be equally divided by diaphragms of the same mesh and gage as the body of the gabions, into cells the length of which does not exceed the horizontal width. The gabion shall be furnished with the necessary diaphragms secured in proper position on the base in a manner that no additional tying at this junction will be necessary.

All perimeter edges of the mesh forming the gabion shall be securely clip-bound or selvaged so that the joints formed by tying the selvages have at least the same strength as the body of the mesh.

Selvage wire used through all the edges (perimeter wire) shall not be less than 3.76 mm diameter (U.S. Wire Gage No.9) and shall meet the same strength and coating specifications as the wire mesh.

Tie and connection wire shall be supplied in sufficient quantity to securely fasten all edges of the gabion and diaphragms and to provide for at least four cross connecting wires in each cell whose height is equal to the width and at least two cross-connecting wires in each cell whose height is one-half the width of the gabion. Cross connecting wires shall not be required when the height of the cell is one-third the width of the gabion. Tie and connection wire shall meet the same strength and coating specifications as the wire used in the mesh, except that it may be as much as two gages 0.68 mm smaller.

In lieu of tie wire, two-gage 7 mm galvanized hog rings may be used to connect adjacent baskets and to secure basket lids. Spacing of the hog rings shall not exceed 150 mm.

Vertical joints in the completed work shall be staggered at approximately one-third or one-half the length of the full baskets.

21.4.7.2. Installation

The gabions shall be placed on a smooth foundation. Final line and grade shall be approved by the Engineer.

Each gabion unit shall be assembled by binding together all vertical edges with wire ties on approximately 150 mm spacing or by a continuous piece of connecting wire stitched around the vertical edges with a coil about every 100 mm. Empty gabion units shall be set to line and grade as shown in the contract documents or as directed by the Engineer. Wire ties, hog rings, or connecting wire shall be used to join the units together in the same manner as described above for assembling. Internal tie wires shall be uniformly spaced and securely fastened in each cell of the structure.
A standard fence stretcher, chain fall, or iron rod may be used to stretch the wire baskets and hold alignment.

The gabions shall be filled with stone carefully placed by hand or machine to ensure alignment and avoid bulges with a minimum of voids. Alternate placing of rock and connection wires shall be performed until the gabion is filled. After a gabion has been filled, the lid shall be bent over until it meets the sides and edges. The lid shall then be secured to the sides, ends, and diaphragms with the wire ties or connecting wire in the manner described above for assembling.

21.4.8. Grouted Riprap

Stones shall be placed on the slope as specified in Article 21.4.5, "Hand-Placing Stones," and shall be thoroughly moistened with water after placement. Grout shall be applied while the stone is moist and shall be worked into the interstices to completely fill the voids.

Where the depth is in excess of 300 mm, the stone shall be placed in 300 mm lifts and each lift grouted prior to placement of the next lift succeeding lifts shall be constructed and grouted before grout in the previous lift has set.

Grout shall be placed only when the weather is suitable and shall be protected from freezing for at least four days. The surface shall be cured by covering with moist earth, wet rugs, or curing blankets for at least three days after grout placement.

Weep holes shall be provided through the riprap as shown in the contract documents or as directed by the Engineer.

21.4.9. Sacked Concrete Riprap

Sacks shall be filled with approximately 0.028 m³ of concrete, leaving room at the top to fold the sacks and retain the concrete during placement. Immediately after being filled, the sacks shall be placed and lightly trampled to conform with the earth face and with adjacent sacks.

The first two courses shall provide a foundation of double thickness. The first foundation course shall consist of a double row of stretchers with the long dimension of the sack parallel to contour of slope laid level and adjacent to each other in a neatly trimmed trench. The trench shall be located as shown in the contract documents or, as directed by the Engineer, cut to the proper depth and width to accommodate placement of the first two foundation courses, and cut back into the slope a sufficient distance to enable proper subsequent placement of the riprap. The second foundation course shall consist of a row of headers with the long dimension at right angles to the stretchers and placed directly above the double row of stretchers. The remaining courses shall consist of stretchers and shall be placed with staggered joints.

Dirt and debris shall be removed from the top of the sacks before the next course is placed. Stretchers shall be placed so that the folded ends are not adjacent. Headers shall be placed with the folds toward the earth face. Not more than four vertical courses of sacks shall be placed in any tier until initial set has taken place in the first course.

When there will not be proper bearing or bond for the concrete because of delays in placing succeeding layers of sacks, a small trench shall be excavated back of the row of sacks and filled with fresh concrete before the next layer of sacks is laid. Header courses may be required at any level to provide additional stability.

Sacked concrete riprap shall be cured with a blanket of wet earth or by sprinkling with a fine spray of water every two hours during the daytime for four days.
Weep holes shall be provided through the riprap as shown in the contract documents or as directed by the Engineer.

21.4.10. Concrete Slope Paving

21.4.10.1. General
This work shall consist of constructing cast-in-place and precast portland cement concrete slope paving. At the option of the Contractor, the cast-in-place slope paving shall be constructed of either Portland cement concrete or pneumatically applied mortar. Where specified in the contract documents or permitted by the Engineer, this work shall also include woven fabric forms filled with fine aggregate Portland cement concrete grout.

21.4.10.2. Cast-in-Place Slope Paving

Concrete shall be mixed and placed in conformance with the provisions in Section 10, "Concrete Structures", and shall be spread and tamped until it is thoroughly compacted and mortar flushes to the surface. If the slope is too steep to permit the use of concrete sufficiently wet to flush with tamping, the concrete shall be tamped until consolidated and a mortar surface 6 mm thick, troweled on immediately. The mortar shall consist of one part portland cement and three parts of fine aggregate. The mortar surface shall be considered as a part of the concrete and no separate payment will be made therefore.

After striking off to grade, the concrete shall be hand floated with wooden floats. Edges and joints shall be edged with a 6 mm radius edger prior to the brooming. The entire surface shall be broomed with a fine texture hair push broom to produce a uniform surface with the broom marks parallel to the edges of the panel.

Pneumatically applied mortar shall be placed and finished in accordance with the provisions in Section 23, "Pneumatically Applied Mortar."

Expansion joints shall be installed transversely at intervals of 6 m. Longitudinal expansion joints shall be installed at the locations shown in the contract documents. Expansion joints shall be filled with expansion joint filler 12 mm thick.

Cast-in-place concrete and pneumatically applied mortar shall be cured as provided in Section 10, "Concrete Structures," and Section 23, "Pneumatically Applied Mortar" respectively.

Weep holes shall be provided through the slope paving as shown in the contract documents or as directed by the Engineer.

When permitted or specified in the contract documents, the Contractor may use woven fabric forms filled with pumpable fine aggregate Portland cement concrete grout as the slope protection system. The request by the Contractor to use a particular system shall be in writing accompanied by working drawings and complete information as to the materials, construction, and performance characteristics of the proposed system.

Pervious backfill material, if required by the contract documents, shall be placed as shown. 0.06 m³ of pervious backfill material wrapped in filter fabric shall be placed at each weep hole and drain hole.

At the completion of the work, footing trenches shall be filled with excavated material and compaction shall not be required.
21.4.10.3. Precast Slope Paving

Precast slabs, blocks, and shapes shall be laid on a 75 mm bed of cushion sand in the pattern shown in the contract documents. Blocks and shapes shall be thoroughly rammed in place to provide a uniformly even surface and solid bedding under each block or shape.

In the areas where grouting is specified in the contract documents or required by the Engineer, the blocks shall be laid in running bond with the length parallel to the slope and with 6 mm joints. Following the laying of the blocks, in the area to be grouted, sufficient mortar sand shall be spread over the surface and swept into the joints to fill the latter to 100 mm from the surface. The blocks shall be wetted to the satisfaction of the Engineer before any grout is placed. The joints shall be filled with grout flush with the top of the block.

After grouting has been completed and the grout has sufficiently hardened, the blocks shall be wetted, covered, and cured with curing blankets or covers for the first seven days after grouting. Grout shall not be poured during freezing weather.

21.5. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and this section requirements. For work acceptance, Contractor shall apply quality control for slope protection work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.

21.5.1. Quality Control

All slope protection works and materials should be controlled and inspected to insure that the work is according to the requirements of materials mentioned in the article 21.3 and Table 21.5 according to the type of material used in the slope protection, also, all shop drawing of the construction should be reviewed and insure that it has enough detailed information.

For work acceptance the construction work procedure should be inspected to insure that is according to the installation requirements mentioned in the article 21.4 for all construction elements according to the used material type.

21.5.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of work, that are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that insure the quality of all works that was finished according to the requirements for this work.

21.6. Measurement and Payment

21.6.1. Measurement

21.6.1.1. Stone Riprap and Filter Blanket

Hand-placed riprap, machine-placed riprap, grouted riprap, and filter blanket aggregate shall be measured by the square meter, or cubic meter, as specified in the contract documents. The area shall be that actually placed to the limiting dimensions.
shown in the contract documents or the dimensions as may have been revised by the Engineer, measured along the upper surface. If measured by the cubic meter, the volume shall be computed on the basis of the measured area and the thickness specified in the contract documents.

21.6.1.2. Sacked Concrete Riprap
Sacked concrete riprap shall be measured by the cubic meter of concrete placed. Measurement shall be based on mixer volumes.

21.6.1.3. Wire-Enclosed Riprap (Gabions)
Wire-enclosed riprap (gabions) shall be measured as the number of square meters of surface area.

21.6.1.4. Cast-in-Place Concrete Slope Paving
Cast-in-place concrete or pneumatically applied mortar slope paving shall be measured in square meters or cubic meters. The area will be that actually placed to the limiting dimensions shown in the contract documents, or the dimensions as may have been revised by the Engineer, measured along the upper sloped surface. If measured in cubic meters, the volume shall be computed on the basis of the measured area and the thickness shown in the contract documents. No additional compensation shall be allowed for additional concrete or pneumatically applied mortar placed by reason of low foundation.

21.6.1.5. Precast Concrete Slope Paving
Precast concrete slabs, blocks, or shapes placed as slope paving shall be measured in square meters computed from the payment lines shown in the contract documents, or as directed by the Engineer.

21.6.1.6. Filter Fabric
Filter fabric shall be measured in square meters on the ground surface, excluding overlaps, complete in place.

21.6.2. Payment

21.6.2.1. General
Payment for slope protection of the various classes at the unit prices bid shall include full compensation for all labor, materials, equipment, or other incidentals in connection with the preparation of sub-grade (except for the furnishing and placement of filter blanket material and filter fabric); excavating and backfilling toe trenches where required; furnishing and placing the stones, slabs, blocks, shapes, grout, mortar, portland cement concrete, pneumatically applied mortar, reinforcing steel, expansion joint filler, if required; and all other work and incidental material required to complete the work as specified in the contract documents.

21.6.2.2. Stone Riprap
Hand-placed riprap, machine-placed riprap, and grouted riprap measured in accordance with Article 21.6.1.1 "Stone Riprap and Filter Blanket," will be paid for at
the price bid per square meter, or per cubic meter, as specified in the contract documents.

21.6.2.3. Sacked Concrete Riprap

Sacked concrete riprap measured in accordance with Article 21.6.1.2, "Sacked Concrete Riprap," shall be paid for at the price bid cubic meter.

21.6.2.4. Wire-Enclosed Riprap (Gabions)

Wire-enclosed riprap (gabions) measured in accordance with Article 21.6.1.3, "Wire-Enclosed Riprap (Gabions)," shall be paid for at the price bid per square meter. Such price shall include wire baskets, connection hardware, anchors, aggregate filling, and any other materials, labor, and equipment necessary to complete the work as specified in the contract documents.

21.6.2.5. Cast-in-Place Concrete Slope Paving

Cast-in-place concrete or pneumatically applied mortar slope paving measured in accordance with 21.6.1.4, "Cast-in-Place Concrete Slope Paving," shall be paid for at the price bid per square meter or per cubic meter as specified in the contract documents.

21.6.2.6. Precast Concrete Slope Paving

Precast concrete slope paving measured in accordance with Article 21.6.1.5, "Precast Concrete Slope Paving," shall be paid for at the price bid per square meter. Such price shall include cushion sand and shall include portland cement grout or mortar, if specified in the contract documents.

21.6.2.7. Filter Blanket

Filter blanket or filter gravel measured in accordance with Article 21.6.1.1, "Stone Riprap and Filter Blanket," shall be paid for at the price bid per square meter, or per cubic meter as specified in the contract documents.

21.6.2.8. Filter Fabric

Filter fabric measured in accordance with Article 21.6.1.6, "Filter Fabric," shall be paid for at the price bid per square meter.

21.6.2.9. Geocomposite Drain System

Geocomposite drain system shall be paid for on the basis of a contract lump-sum price. Such lump-sum price shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing geocomposite drain systems complete in place including geocomposite drain, collection, and discharge systems as shown in the contract documents and as directed by the Engineer.

Payment will be made under one or more of the items in Table 21.3. And quality control requirements for slope protection are shown in Table 21.4.
Table 21.3: Slope Protection Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>21.3.1</td>
<td>Stone Riprap</td>
<td>Square Meter</td>
</tr>
<tr>
<td>21.3.2</td>
<td>Wire-Enclosed Riprap (Gabions)</td>
<td>Square Meter</td>
</tr>
<tr>
<td>21.3.3</td>
<td>Filter Fabric</td>
<td>Square Meter</td>
</tr>
<tr>
<td>21.3.4</td>
<td>Sacked Concrete Riprap</td>
<td>Cubic</td>
</tr>
<tr>
<td>21.3.5</td>
<td>Cast-in-Place Concrete Slope Paving</td>
<td>Square or Cubic Meter</td>
</tr>
<tr>
<td>21.3.6</td>
<td>Pneumatically Applied Mortar</td>
<td>Square or Cubic Meter</td>
</tr>
<tr>
<td>21.3.7</td>
<td>Pre-cast Concrete Slope Paving</td>
<td>Square Meter</td>
</tr>
</tbody>
</table>

Table 21.4: Quality Control Requirements For Slope Protection

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of Slopes</td>
<td>Shaped and compacted to 95 percent standard density</td>
<td>AASHTO T 99</td>
<td>In situ</td>
<td>directed by the engineer</td>
<td>Article 21.4.1</td>
</tr>
<tr>
<td>Bedding</td>
<td>Layer of filter gravel</td>
<td>Thickness measurement</td>
<td>In situ</td>
<td>0</td>
<td>Article 21.4.2</td>
</tr>
<tr>
<td>Filter Fabric</td>
<td>Spread uniformly over the prepared slope or surface</td>
<td>Visual inspection and measurement</td>
<td>In situ</td>
<td>0</td>
<td>Article 21.4.3</td>
</tr>
<tr>
<td>Geo-composite Drain</td>
<td>Minimum overlap and corrugations placing</td>
<td>Visual inspection and measurement</td>
<td>In situ</td>
<td>0</td>
<td>Article 21.4.4</td>
</tr>
<tr>
<td>Hand-Placing Stones</td>
<td>Placing stones and filling Interstices</td>
<td>Visual inspection and placing checkup</td>
<td>In situ</td>
<td>0</td>
<td>Article 21.4.5</td>
</tr>
<tr>
<td>Machine-Placed Stones</td>
<td>Dry Placement</td>
<td>Visual inspection and placing checkup</td>
<td>In situ</td>
<td>0</td>
<td>Article 21.4.6.1</td>
</tr>
<tr>
<td></td>
<td>Underwater Placement</td>
<td>Visual inspection and placing checkup</td>
<td>In situ</td>
<td>0</td>
<td>Article 21.4.6.2</td>
</tr>
<tr>
<td>Wire-Enclosed Riprap (Gabions)</td>
<td>Each gabion unit is assembled by binding together with wire ties on approximately 150 mm spacing</td>
<td>Visual inspection and placing checkup</td>
<td>In situ</td>
<td>0</td>
<td>Article 21.4.7</td>
</tr>
<tr>
<td></td>
<td>Grouted Riprap</td>
<td>Visual inspection and placing checkup</td>
<td>In situ</td>
<td>0</td>
<td>Article 21.4.8</td>
</tr>
</tbody>
</table>
### Table 21.5: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>see table 21-1</td>
<td>AASHTO T-85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>see table 21-1</td>
<td>AASHTO T-210</td>
<td></td>
<td></td>
</tr>
<tr>
<td>the tensile</td>
<td></td>
<td>ASTM A 392</td>
<td></td>
</tr>
<tr>
<td>strength of the</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wire shall be</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in the range</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of 415 to 585</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MPA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The minimum</td>
<td>AASHTO T 65M/T 65</td>
<td>ASTM A 90/</td>
<td></td>
</tr>
<tr>
<td>zinc coating of</td>
<td></td>
<td>A 90M</td>
<td></td>
</tr>
<tr>
<td>the wire shall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>be 0.25 kg/m²</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of uncoated wire</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M288</td>
<td></td>
<td></td>
</tr>
<tr>
<td>as specified</td>
<td></td>
<td>ASTM C270</td>
<td></td>
</tr>
</tbody>
</table>

The tensile strength of the wire shall be in the range of 415 to 585 MPa.

The minimum zinc coating of the wire shall be 0.25 kg/m² of uncoated wire surface.

The table includes the following standards:
- Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate
- Standard Method of Test for Aggregate Durability Index
- Standard Specification for Zinc-Coated Steel Chain-Link Fence Fabric
- Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
- Standard Specification for Geotextile Specification for Highway Applications
- Standard Specification for Mortar for Unit Masonry
<table>
<thead>
<tr>
<th>Specifications</th>
<th>Codes/Standards</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>as specified</td>
<td>ASTM C150</td>
<td>Standard Specification for Portland Cement</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 45</td>
<td>Standard Specification for Aggregate for Masonry Mortar. American Association of State Highway and Transportation</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM C 129</td>
<td>“Standard Specification for Nonloadbearing Concrete Masonry Units”</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM C 139</td>
<td>“Standard Specification for Concrete Masonry Units for Construction of Catch Basins and Manholes”</td>
</tr>
<tr>
<td>as specified</td>
<td>ASTM C 90</td>
<td>“Standard Specification for Loadbearing Concrete Masonry Units”</td>
</tr>
<tr>
<td>the underlying material shall be compacted to 95 percent (95%) standard density as specified in AASHTO T 99</td>
<td>AASHTO T 99</td>
<td>Standard Method of Test for the Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop</td>
</tr>
</tbody>
</table>

### 21.7. References

AASHTO LRFD. “Construction Specifications Second Edition 2004 - Sec. 22 ”

SECTION 22. MISCELLANEOUS METAL

22.1. Description
This work shall consist of furnishing and installing miscellaneous iron and steel, miscellaneous metal (bridge), miscellaneous metal (restrainer), and pumping plant metal work, all as shown on the plans or as directed by the Engineer, and as specified in these specifications and the special provisions.

Miscellaneous iron and steel, miscellaneous metal (bridge), and miscellaneous metal (restrainer) will be inspected at the fabrication site. The Contractor shall notify the Engineer when materials have been delivered to the fabrication site and shall give the Engineer at least 10-days notice after delivery before commencing the fabrication of the miscellaneous metal. Materials to be used shall be made available to the Engineer so they can be examined. The Engineer shall have free access at all times to any portion of the fabrication site where the material is stored or where work on the material is being performed.

22.2. Miscellaneous Iron and Steel
Miscellaneous iron and steel items shall conform to the dimensions and details shown on the plans and as specified in these specifications and the special provisions.

At the option of the Contractor, grates shall be fabricated from either structural steel conforming to the requirements in ASTM A 36/A 36M or A 576 Grades 1021, 1022, 1026, 1029 or 1030, ductile iron castings, or carbon steel castings.

Welding shall conform to the requirements in AWS D1.1.

Fabrication shall be performed in a workmanlike manner in conformance with the practice in modern commercial shops. Burrs, rough and sharp edges, and other flaws shall be removed. Warped pieces shall be straightened after all fabrication and galvanizing.

Manhole frames and covers shall be fabricated from gray cast iron.

Unless otherwise specified all steel items and cast iron lightweight sidewalk frames and covers shall be galvanized in conformance with the provisions in "Galvanizing" Galvanizing shall be performed after fabrication and before assembling component parts. All other cast iron items shall be painted with or dipped in commercial quality asphaltum.

Drainage inlet frames and grates, except those which are to be on bridges, need not be galvanized or coated with asphalt paint.

Frames and grates, or frames and covers shall be matchmarked in pairs before delivery to the work and the grates and covers shall fit into their frames without rocking.

Unless otherwise specified, materials shall conform to the specifications in Table 22.1.
Table 22.1: Materials Specifications

<table>
<thead>
<tr>
<th>Material</th>
<th>ASTM Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel bars, plates and shapes</td>
<td>ASTM A 36/A 36M or A 575, A 576 (AISI or M Grades 1016 through 1030 except Grade 1017)</td>
</tr>
<tr>
<td>Steel fastener components for general applications:</td>
<td></td>
</tr>
<tr>
<td>Bolts and studs</td>
<td>ASTM A 307</td>
</tr>
<tr>
<td>Headed anchor bolts</td>
<td>ASTM A 307, Grade B, including S1 supplementary requirements</td>
</tr>
<tr>
<td>Non-headed anchor bolts</td>
<td>ASTM A 307, Grade C, including S1 supplementary requirements and S1.6 of AASHTO M 314 supplementary requirements or AASHTO M 314, Grade 250 or 380, including S1 supplementary requirements</td>
</tr>
<tr>
<td>High-strength bolts and studs, threaded rods, and non-headed anchor bolts</td>
<td>ASTM A 449, Type 1</td>
</tr>
<tr>
<td>Nuts</td>
<td>ASTM A 563, including Appendix X1*</td>
</tr>
<tr>
<td>Washers</td>
<td>ASTM F 844</td>
</tr>
<tr>
<td>Components of high-strength steel fastener assemblies for use in structural steel joints:</td>
<td></td>
</tr>
<tr>
<td>Bolts</td>
<td>ASTM A 325, Type 1</td>
</tr>
<tr>
<td>Tension control bolts</td>
<td>ASTM F 1852, Type 1</td>
</tr>
<tr>
<td>Nuts</td>
<td>ASTM A 563, including Appendix X1*</td>
</tr>
<tr>
<td>Hardened washers</td>
<td>ASTM F 436, Type 1, Circular, including S1 supplementary requirements</td>
</tr>
<tr>
<td>Direct tension indicators</td>
<td>ASTM F 959, Type 325, zinc-coated</td>
</tr>
<tr>
<td>Stainless steel fasteners (Alloys 304 &amp; 316) for general applications:</td>
<td></td>
</tr>
<tr>
<td>Bolts, screws, studs, threaded rods, and non-headed anchor bolts</td>
<td>ASTM F 593 or F 738M</td>
</tr>
<tr>
<td>Nuts</td>
<td>ASTM F 594 or F 836M</td>
</tr>
<tr>
<td>Washers</td>
<td>ASTM A 240/A 240M and ANSI B 18.22M</td>
</tr>
<tr>
<td>Carbon-steel castings</td>
<td>ASTM A 27/A 27M, Grade 450-240, Class 1</td>
</tr>
<tr>
<td>Malleable iron castings</td>
<td>ASTM A 47, Grade 32510 or A 47M, Grade 22010</td>
</tr>
<tr>
<td>Gray iron castings</td>
<td>ASTM A 48, Class 30B</td>
</tr>
<tr>
<td>Ductile iron castings</td>
<td>ASTM A 536, Grade 450-310-85</td>
</tr>
<tr>
<td>Cast iron pipe</td>
<td>Commercial quality</td>
</tr>
<tr>
<td>Steel pipe</td>
<td>Commercial quality, welded or extruded</td>
</tr>
<tr>
<td>Other parts for general applications</td>
<td>Commercial quality</td>
</tr>
</tbody>
</table>

* Zinc-coated nuts that will be tightened beyond snug or wrench tight shall be furnished with a dyed dry lubricant conforming to Supplementary Requirement S2 in ASTM A563.
22.3. Miscellaneous Bridge Metal

Miscellaneous bridge metal shall conform to the provisions in Article 22.2 "Miscellaneous Iron and Steel," and the provisions in this section. Miscellaneous metal used in constructing bridges and other structures described as bridge work in the special provisions, excepting miscellaneous metal in pumping plants and miscellaneous metal identified on the plans or in these specifications for which payment is made under separate contract items, shall conform to the details shown on the plans and as specified in these specifications and the special provisions.

Miscellaneous bridge metal shall consist of the following:

1. Bearing assemblies, equalizing bolts and expansion joint armor in concrete structures.
2. Expansion joint armor in steel structures.
3. Manhole frames and covers, frames and grates, ladder rungs, guard posts and access door assemblies.
4. Deck drains, area drains, retaining wall drains and drainage piping.

Bearing assemblies shall be fabricated from structural steel conforming to the requirements in ASTM A 36/A 36M.

High-strength bolted connections shall conform to the provisions for high-strength steel fasteners and bolted connections in Article 13.3.2 “High Strength Fasteners’, in Section 13, "Steel Structures’.

Equalizing bolts shall consist of bolts or threaded bars. Threaded bars identified as prestressing steel on the plans shall conform to the requirements for plain bars in ASTM A 722, including Supplementary Requirements. When noted on the plans, nuts, bolts, threaded bars and plate washers shall be cleaned by "Blast Cleaning," or "Hand Cleaning," at the option of the Contractor. All surfaces, except the portion of threads engaged by nuts, shall be painted with 2 applications of unthinned zinc-rich primer (organic vehicle type) conforming to the provisions in Section 15, "Painting”. Aerosol cans shall not be used. The second application shall be applied to nuts and threads after installation.

An approved thread locking system, consisting of a cleaner, primer and anaerobic adhesive shall be applied where shown on the plans. Lubricants and foreign materials shall be removed from the threaded areas of both parts using the cleaner and small wire brush. The primer shall be applied to cover the threaded areas of both parts. The anaerobic adhesive shall be applied to fill the male threads in the area of the final position of the nut. The nut shall be installed at the location or to the torque shown on the plans, and an additional fillet of anaerobic adhesive shall be applied completely around the exposed junctions of the nut and male part.

Access opening covers shall be fabricated from commercial quality sheet steel.

Sheet steel for access doors shall be galvanized sheet conforming to the requirements in ASTM A 526/A 526M, Coating Designation G 210.

Springs for deck drain grating latches shall be made from commercial quality stainless steel spring wire containing a nominal composition of eighteen percent (18%) chromium and eight percent (8%) nickel. Spring latches and other mechanical devices shall be tested before delivery to the work and shall operate smoothly and properly.

Cast steel and cast iron shall conform to the provisions in Section 13, "Steel Structures".
Pipe bends shall be commercial quality tube bends or fabricated bends of substantially equal smoothness. Miter-joint bends will not be accepted.

Transition fittings between pipes of different diameters shall be smooth, uniform, without sags, projections or offsets, and shall be at least 100 mm in length for each 25mm reduction in pipe diameter.

Mechanical expansion anchors shall be the integral stud type or the shell type with internal threads and an independent stud. Self-drilling mechanical expansion anchors shall not be used.

All metal parts of anchorage devices shall be fabricated from steel or stainless steel, except iron castings for cast-in-place inserts shall be malleable iron or ductile iron.

Mechanical expansion and resin capsule anchors shall, when installed in accordance with the manufacturer's instructions and these specifications, withstand the application of a sustained tension test load of at least the values in Table 22.2 for a period of at least 48 hours with a movement not greater than 0.9 mm.

<table>
<thead>
<tr>
<th>Stud Diameter (mm)</th>
<th>Sustained Tension Test Load (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.01-33.00</td>
<td>137.9</td>
</tr>
<tr>
<td>25.01-29.00</td>
<td>79.6</td>
</tr>
<tr>
<td>21.01-25.00</td>
<td>64.1</td>
</tr>
<tr>
<td>19.01-21.00*</td>
<td>22.2</td>
</tr>
<tr>
<td>15.01-19.00</td>
<td>18.2</td>
</tr>
<tr>
<td>12.01-15.00</td>
<td>14.2</td>
</tr>
<tr>
<td>9.01-12.00</td>
<td>9.34</td>
</tr>
<tr>
<td>6.00-9.00</td>
<td>4.23</td>
</tr>
</tbody>
</table>

* Maximum stud diameter permitted for mechanical expansion anchors.

Cast-in-place inserts shall, when installed in conformance with the manufacturer's instructions and these specifications, withstand the minimum ultimate tensile loads indicated in Table 22.3.

<table>
<thead>
<tr>
<th>Stud Diameter (mm)</th>
<th>Ultimate Tensile Load (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-33</td>
<td>112.1</td>
</tr>
<tr>
<td>27-30</td>
<td>88.1</td>
</tr>
<tr>
<td>24-27</td>
<td>71.2</td>
</tr>
<tr>
<td>20-24</td>
<td>51.6</td>
</tr>
<tr>
<td>16-20</td>
<td>32.0</td>
</tr>
<tr>
<td>14-16</td>
<td>29.4</td>
</tr>
<tr>
<td>12-14</td>
<td>18.7</td>
</tr>
</tbody>
</table>

Concrete anchorage devices shall be subject to the approval of the Engineer. Approval of anchorage device types and sizes shall be contingent upon the Contractor submitting to the Engineer one sample of each type of concrete anchorage device, manufacturer's installation instructions and certified results of tests, either by a private testing laboratory or the manufacturer, indicating compliance with the above
requirements. Anchorage devices previously tested and found to be in compliance with the above requirements and approved by the Engineer need not be retested.

Concrete anchorage devices shall be installed in the concrete as shown on the plans, as recommended by the manufacturer of the devices, and as specified herein, so that the attached equipment or fixtures will bear firmly against the concrete. Shell type mechanical expansion anchors shall be installed so that the top surface of the anchor body remains 12 mm to 25 mm below the surface of the concrete after expansion. After installation of shell type mechanical expansion anchors, and prior to mounting any equipment or fixture, the Contractor shall demonstrate in the presence of the Engineer that the expansion anchor is firmly seated within the above tolerances.

If the manufacturer's instructions do not include specific torque requirements, nuts used to attach equipment or fixtures to anchorage devices shall be tightened to the following installation torque values in newton meters indicated in Table 22.4.

Table 22.4: Installation Torque Values, (Newton meters)

<table>
<thead>
<tr>
<th>Stud Diameter (millimeters)</th>
<th>Shell Type Mechanical Expansion Anchors</th>
<th>Integral Stud Type Mechanical Expansion Anchors</th>
<th>Resin Capsule Anchors and Cast-in-Place Inserts</th>
</tr>
</thead>
<tbody>
<tr>
<td>29.01-33.00</td>
<td>—</td>
<td>—</td>
<td>650</td>
</tr>
<tr>
<td>25.01-29.00</td>
<td>—</td>
<td>—</td>
<td>400</td>
</tr>
<tr>
<td>21.01-25.00</td>
<td>—</td>
<td>—</td>
<td>290</td>
</tr>
<tr>
<td>19.01-21.00</td>
<td>110</td>
<td>235</td>
<td>180</td>
</tr>
<tr>
<td>15.01-19.00</td>
<td>45</td>
<td>120</td>
<td>90</td>
</tr>
<tr>
<td>12.01-15.00</td>
<td>30</td>
<td>65</td>
<td>40</td>
</tr>
<tr>
<td>9.01-12.00</td>
<td>15</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>6.00-9.00</td>
<td>5</td>
<td>10</td>
<td>7</td>
</tr>
</tbody>
</table>

Joints in drain pipe shall be watertight, and shall be smooth and free from projections or offsets in excess of 2 mm on the inside. Mechanical couplings in piping shall be gasketed short sleeve type couplings consisting of a mild steel middle ring with pipe stop, 2 rubber-compounded wedge-section ring gaskets, 2 mild steel follower rings and sufficient mild steel bolts to compress the gaskets.

Galvanizing of miscellaneous bridge metal will not be required for portions of plates, shapes or other items embedded more than 50 mm in concrete; embedded steel pipe terminating at or below the surface of encasing concrete; and items shown on the plans to receive other finish.

Where local conditions require that pipes under walkways and other improved areas be of smaller diameter than the down-drain pipes, a transition section shall be provided.

During construction operations, deck drain grates and other grating openings shall be securely covered to prevent intrusion of debris until after final cleanup of the deck and other drainage areas.

After the cleanup of the deck and other drainage areas, each drain pipe and facility, except short free fall pipes, shall be tested in the presence of the Engineer by discharging approximately 400 liters of water into the drain to demonstrate the proper operation of the drain pipe and facility. If evidence of obstructions in the pipe is
observed, the pipe shall be cleared and the test repeated until the drain pipe and facility are unobstructed.

22.4. Bridge Joint Restrainer Units

Bridge joint restrainer units, of the type or types shown on the plans, consisting of cables or cable assemblies and associated materials or components, shall conform to the details shown on the plans and the requirements of these specifications and the special provisions.

The associated materials or components required for each restrainer unit type shall be as shown on the plans or as specified in the special provisions and include various combinations of the following: structural steel components, bolts, bearing plates, cable drum units, pipe sleeves, polyvinyl chloride pipe, elastomeric pads, expansion joint filler, expanded neoprene, expanded polystyrene, sheet neoprene, hardboard and incidentals.

Cables shall be 19 mm preformed, 6×19, wire strand core or independent wire rope core (IWRC), galvanized, and in conformance with the requirements in Specification RR W 410D, right regular lay, manufactured of improved plow steel with a minimum breaking strength of 200 kN.

Cable assemblies shall consist of cables, swaged fittings, studs, nuts, cable yield indicators, disk springs and when shown on the plans, turnbuckles and shall conform to the following requirements:

- The swaged fitting shall be machined from hot rolled bars of steel conforming to the requirements in AISI Designation: C1035, and shall be annealed, suitable for cold swaging. A lock pin hole to accommodate a 6 mm plated spring steel pin shall be drilled through the head of the swaged fitting to retain the stud in proper position. The manufacturer's identifying mark shall be stamped on the body of the swaged fitting.
- The 25 mm diameter stud shall conform to the requirements in ASTM A 449 after galvanizing. Prior to galvanizing, a 10 mm slot for the locking pin shall be milled in the stud end.
- Nuts shall conform to the requirements in ASTM A 563 or A 563M including Appendix X1, except lubrication is not required.
- The cable yield indicator shall be machined from hot rolled bars of steel conforming to the requirements in AISI Designation: C 1035 and shall be annealed, suitable for cold swaging. The heat number and manufacturer's identifying mark shall be stamped on the end surface of each cable yield indicator. The wall thickness of the reduced section of the cable yield indicator shall be machined by the Contractor so that the indicator yields at a load between 160.2 kN and 169.1 kN when tested in compression along the major axis at a test speed not to exceed 12 mm per minute.
- The disc springs shall be made from steel conforming to the requirements in ASTM A 684/A 684M, Grade 1075. Galvanizing of the disc springs will not be required. The disc springs shall be cleaned and painted with a paint recommended by the manufacturer and color coded as shown on the plans.
- Turnbuckles shall be the steel pipe type. Pulls for the turnbuckles shall consist of a swaged fitting and stud assembly.
• The swaged fittings, turnbuckles, stud and nut assembly shall develop the specified breaking strength of the cable.
• The cable assemblies shall be shipped as a complete unit including cable yield indicator, disk springs, stud and nut and, when required, turnbuckle.
• The Contractor shall be responsible for determining the required lengths of the cable assemblies.
• The Contractor shall notify the Engineer, in writing, at least 2 days prior to tightening and setting of cable restrainer units.

The following materials shall be furnished to the Engineer at the manufacturer's plant:
• One sample cable assembly, consisting of a cable properly fitted with a swaged fitting and right hand thread stud at both ends, one meter (1 m) in total length, for each 200 cable assemblies or fraction thereof produced.
• One turnbuckle fitted with a 200mm stud at each end for each 200 turnbuckles or fraction thereof produced.
• One percent of the cable yield indicators, but not fewer than 8, produced from each mill heat.
• Two disc springs of each size produced from each mill heat.

Free ends of cable for restrainer units shall be securely wrapped at each end to prevent separation.

Bolts, thread locking system and concrete anchorage devices shall conform to the provisions in Article 22.3, "Miscellaneous Bridge Metal".

Unless otherwise specified, steel parts shall conform to the requirements in ASTM A 36/A 36M. Steel for bearing bars or pins shall conform to the requirements in ASTM A 36/A 36M or A 576 Grade 1030 (AISI 1030) and shall be other than rimmed or capped steel.

Pipe sleeves shall be commercial quality welded steel pipe.

Steel parts shall be galvanized in conformance with the provisions in Article 22.7, "Galvanizing".

Fabrication and welding shall conform to the provisions in Article 22.3, "Miscellaneous Bridge Metal." The minimum size of fillet welds shall conform to the requirements in AWS D1.1 except as indicated in Table 22.5.

<table>
<thead>
<tr>
<th>Base Metal Thickness of Thicker Part Joined (mm)</th>
<th>Minimum Size of Fillet Weld (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 19 to 38</td>
<td>8</td>
</tr>
<tr>
<td>Over 38 to 57</td>
<td>10</td>
</tr>
<tr>
<td>Over 57 to 150</td>
<td>13</td>
</tr>
<tr>
<td>Over 150</td>
<td>16</td>
</tr>
</tbody>
</table>
Concrete for filling cable drum units shall conform to the provisions in Article 10.19, "Concrete for Minor Structures", or shall be a commercial grade pea gravel mix with not less than 400 kilograms of cement per cubic meter.

Existing structural steel paint areas damaged by the Contractor's operations and holes drilled through existing steel members shall be repaired in conformance with the provisions for repair of galvanized surfaces in Article 22.7, "Galvanizing" at the Contractor's expense.

When shown on the plans, bond breaker on PVC pipe shall consist of a mortar tight wrapping of plastic sheet or rubber sheet, 0.25 mm minimum thickness, or equal.

Expansion joint filler shall conform to the provisions in Article 10.11.2.1, "Premolded Expansion Joint Fillers".

Closed cell expanded neoprene material shall be of commercial quality conforming to the stiffness requirements for Class SC Grade 43E material or firmer as set forth in ASTM D 1056.

Each restrainer unit shall consist of the number of cable units shown on the plans.

Where shown on the plans, the cable shall be covered with a piece of 19 mm inside diameter neoprene tubing having a wall thickness of not less than 3 mm. Neoprene tubing shall be held in place with stainless steel hose clamps. Neoprene tubing and hose clamps shall be of commercial quality. Cadmium plated screws furnished with stainless steel clamps will be acceptable.

22.5. Pumping Plant Metal Work

Pumping plant metal work shall conform to the provisions in Article 22.3, "Miscellaneous Iron and Steel," and the provisions in this section. Pumping plant metal work consisting of fabricated and cast metal parts involved in the construction of pumping plants, including metal parts in the pumphouse, outside stairway, storage box and discharge box and the roadway type inlet frames and grates at the pumping plant site; but excluding bar reinforcing steel, and excluding roadway type inlet frames and grates listed and paid for under the contract item of miscellaneous iron and steel, shall be furnished and installed in accordance with the details shown on the plans and as required in these specifications.

Cast iron manhole covers and frames and cast iron grates and frames (except in walkway areas) and other items as shown on the plans shall be dipped in commercial quality asphaltum.

Manhole covers and frames for pumping plant discharge boxes shall be watertight and certified by the manufacturer to be rated to the pressure shown on the plans. Modifications to the manhole cover and frame by the Contractor to achieve pressure rating will not be allowed.

22.6. Fabrication

Fabrication of miscellaneous metal items shall be performed in a manner in conformance with the practice in modern commercial shops. Burrs, rough and sharp edges, and other flaws shall be removed. Warped pieces shall be straightened after fabrication and galvanizing.
22.7. Galvanizing

Unless otherwise specified in the contract documents, all steel items which are not embedded at least 50 mm in concrete and all cast iron sidewalk frames and covers shall be galvanized in accordance with Article 13.3.2.4, "Galvanized High-Strength Fasteners" and Article 13.3.7, "Galvanizing," in Section 13, “Steel Structures”. Assemblies shall be galvanized after fabrication.

22.8. Measurement and Payment

22.8.1. Measurement

Measurement of miscellaneous metal shall be by the scale weight. When requested by the Engineer, each delivery shall be accompanied with a certified weigh master's ticket. Scale weight is not required when calculated weight is shown in the contract documents, in which case this weight shall be used as the basis of payment.

22.8.2. Payment

Miscellaneous metal shall be paid for by the contract unit price per kilogram. Such payment shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in furnishing and installing miscellaneous metal, complete in place, as specified in the contract documents, specified in these Specifications, and as directed by the Engineer.

Payment will be made as indicated in Table 22.6. And Quality Control Requirements For Miscellaneous Metal are shown in Table 22.7.

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.1</td>
<td>Miscellaneous Metal</td>
<td>Kilogram</td>
</tr>
</tbody>
</table>

Table 22.7: Quality Control Requirements For Miscellaneous Metal

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fabrication</td>
<td>Fabrication of miscellaneous metal items shall be performed in a manner in conformance with the practice in modern commercial shops</td>
<td>Conformity and checkup</td>
<td>------</td>
<td>Each</td>
<td>Article 22.6</td>
</tr>
</tbody>
</table>
### Table 22.8: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>As specified</td>
<td>ASTM A 36/A 36M</td>
<td></td>
<td>Standard Specification for Carbon Structural Steel</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 307</td>
<td></td>
<td>Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO M 314</td>
<td></td>
<td>Standard Specification for Steel Anchor Bolts AMERICAN IRON AND STEEL INSTITUTE (AISI)</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 449</td>
<td></td>
<td>Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 563</td>
<td></td>
<td>Standard Specification for Carbons and Alloy Steel Nuts</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM F 844</td>
<td></td>
<td>Standard Specification for Washers, Steel, Plain (Flat), Unhardened for General Use</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 325</td>
<td></td>
<td>Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM F 1852</td>
<td></td>
<td>Standard Specification for Twist Off Type Tension Control Structural Bolt/Nut/Washer Assemblies, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM F 436</td>
<td></td>
<td>Standard Specification for Hardened Steel Washers</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM F 959</td>
<td></td>
<td>Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM F 593 or F 738M</td>
<td></td>
<td>Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM F 594 or F 836M</td>
<td></td>
<td>Standard Specification for Style 1 Stainless Steel Metric Nuts</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 536</td>
<td></td>
<td>Standard Specification for Ductile Iron Castings</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 27/A 27M</td>
<td></td>
<td>Standard Specification for Steel Castings, Carbon, for General Application</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 47</td>
<td></td>
<td>Standard Specification for Ferritic Malleable Iron Castings</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 48</td>
<td></td>
<td>Standard Specification for Gray Iron Castings</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 240/A 240M</td>
<td>Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>-------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 722</td>
<td>Standard Specification for Uncoated High-Strength Steel Bars for Prestressing Concrete</td>
<td></td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM D 1056</td>
<td>Standard Specification for Flexible Cellular Materials—Sponge or Expanded Rubber</td>
<td></td>
</tr>
</tbody>
</table>

### 22.9. References

AISI Designation: “American Iron and Steel Institute” C1035.


ANSI “American National Standards Institute”-B 18.22M.


CALIFORNIA: “Standard Specifications State Of California Business, Transportation And Housing Agency Department Of Transportation May 2006”- Sec. 75

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SECTION 23. PNEUMATICALLY APPLIED MORTAR (SHOTCRETE)

23.1. General

23.1.1. Description
This work shall consist of furnishing and placing of pneumatically applied mortar (wet and dry process) for the construction of portions of structures, repairing concrete structures, texturing concrete surfaces, encasement of structural steel members, lining ditches and channels, paving slopes, and for other miscellaneous work, all as specified in the contract documents.

This work shall also include the preparation of surfaces to receive the mortar and the furnishing and placing of any reinforcing steel and anchors for reinforcement.

23.1.2. Definitions
The following definitions cover terms used in this Section:

- **Curing Compound**: A liquid that is sprayed or otherwise applied to newly placed concrete which retards the loss of water during curing.
- **Dry-mix mortar**: Mortar in which most of the mixing water is added at the nozzle.
- **Nozzle**: Attachment at end of delivery hose from which shotcrete is projected at high velocity.
- **Nozzle-man**: (in Dry-Mix Process) is an individual who has demonstrated the knowledge and ability to properly place dry-mix shotcrete.
- **Shotcrete**: Mortar or concrete pneumatically projected at high velocity onto a surface.
- **Wet-mix mortar**: Mortar in which all of the ingredients, including water, are mixed before introduction into the delivery hose; compressed air is introduced to the material flow at the nozzle.

23.2. Contractor Qualifications

23.2.1. General
The quality of a completed mortar application results from the combined skills and knowledge of the shotcrete crew. The foreman and crew should have performed satisfactory work in similar capacities for a specified period.
23.2.1.1. Foreman
The foreman normally has proficiency at all crew positions and is in charge of the crew. The foreman typically shall have at least one year of experience on pneumatically applied mortar projects.

23.2.1.2. Nozzle Operator
The nozzle operator shall have completed at least one similar application as a nozzle operator on a similar project. The nozzle operator should also be able to demonstrate, by test, an ability to satisfactorily perform the required duties and to apply shotcrete as required by specifications.

23.2.1.3. Finisher or Rodman
The finisher or rodman should have mortar experience; however, if his previous work experience provided acceptable results, this should qualify the finisher or rodman for the position.

23.2.1.4. Gun or Pump Operator
The gun or pump operator should be familiar with and be able to operate the pneumatically applied mortar delivery equipment, know the proper methods of material preparation and mixing, and be familiar with the communication method in use. Preferably, the pump operator should have at least one year of experience as a gun or pump operator.

23.3. Materials

23.3.1. Cement (ACI 506R)
Most shotcrete is produced with Type I or I-II cements conforming to ASTM C 150 or C 595. Other cementitious materials, such as blended hydraulic cements, should meet ASTM C 1157.

23.3.2. Aggregate

23.3.2.1. Normalweight Aggregate
Normalweight aggregate for mortar should comply with the requirements of ASTM C 33. The combined aggregate should meet one of the gradations shown in Table 23.1. Grading No. 1 should be used for fine-aggregate mortar and Grading No. 2 for all other mortar.

Aggregates failing to comply with the gradations shown in Table 23.1 may be used if preconstruction testing proves satisfactory results or if acceptable service records of previous use are available.

23.3.2.2. Lightweight Aggregates
Lightweight aggregates should conform to ASTM C 330 if used in mortar. The aggregate should meet one of the gradations shown in Table 23.1. Wet-mix shotcrete with lightweight aggregate may be difficult to pump or shoot because the aggregate absorbs water, which reduces the plasticity of the mixture. Presaturating the lightweight aggregate before batching reduces loss of pumpability.
23.3.2.3. Recovered Rebound

Recovered rebound shall be clean and free of foreign material to be reused as fine aggregate in quantities not to exceed twenty percent (20\%) of the total fine aggregate requirements.

Table 23.1: Grading limits for combined aggregates

<table>
<thead>
<tr>
<th>Sieve size, U.S. standard square mesh</th>
<th>Percent by weight passing individual sieves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grading No. 1</td>
</tr>
<tr>
<td>19 mm</td>
<td>—</td>
</tr>
<tr>
<td>12 mm</td>
<td>—</td>
</tr>
<tr>
<td>10 mm</td>
<td>100</td>
</tr>
<tr>
<td>No. 4 (4.75 mm)</td>
<td>95 to 100</td>
</tr>
<tr>
<td>No. 8 (2.4 mm)</td>
<td>80 to 98</td>
</tr>
<tr>
<td>No. 16 (1.2 mm)</td>
<td>50 to 85</td>
</tr>
<tr>
<td>No. 30 (600 μm)</td>
<td>25 to 60</td>
</tr>
<tr>
<td>No. 50 (300 μm)</td>
<td>10 to 30</td>
</tr>
<tr>
<td>No. 100 (150 μm)</td>
<td>2 to 10</td>
</tr>
</tbody>
</table>

23.3.3. Water

23.3.3.1. Mixing Water

Mixing water shall conform to the requirements in Article [10.4.4], “Water” in Section 10, “Concrete Structures”.

23.3.3.2. Curing Water

Curing water should be free from substances that may be injurious to concrete. Water for curing architectural mortar should be free from elements that cause staining. The temperature of the curing water should not be lower than ten degrees Celsius (10°C) cooler than the mortar surface at the time the water and mortar come into contact.

23.3.4. Other Materials

Bonding compounds are generally not required nor recommended for use in pneumatically applied mortar work because the bond of shotcrete to properly prepared substrates is normally excellent.

If required, epoxy or latex materials are available and the job requires their use, the manufacturer's instructions should be followed. Improperly used bonding compounds can act as bond breakers.

Preconstruction trials should precede any extensive use of a bonding compound.

23.3.5. Admixtures

Admixtures used in pneumatically applied mortar shall meet the requirements in Article [10.4.3], “Admixtures” in Section 10, “Concrete Structures”.

23.3.6. Reinforcement

23.3.6.1. Reinforcing Bars

Reinforcing bars used in mortar should conform to ASTM standards.
Mortar construction requires care in the spacing and arrangement of reinforcement because heavy concentrations of steel interfere with the mortar stream. As bar size increases or if the spacing decreases, the nozzle operator’s skill becomes increasingly important to ensure complete encasement. Bar lap splices, couplers, number of curtains, and depth of section also interfere with the shotcrete stream, which further complicates encasement and requires careful attention by the nozzle operator.

Reinforcement should be free from oil, loose rust, mill scale, or other surface deposits that may affect its bond to the mortar.

23.3.6.2. Wire Reinforcement

Welded-wire reinforcement should conform to ASTM A 185 or ASTM A 497 and may be uncoated or galvanized.

Commonly used fabric gages are W2 or W1.4 (4 or 3 mm) wire, spaced 100 mm in both directions.

Galvanized mesh is sometimes specified to reduce the possibility of corrosion of the mesh in aggressive environments. Care, however, should be taken when specifying the use of galvanized mesh to avoid creating other problems. Galvanized mesh can induce galvanic action when in contact with other nongalvanized steel.

23.3.6.3. Epoxy-Coated Reinforcement

Due to the abrasive nature of the mortar process, especially the dry-mix process, using epoxy-coated reinforcement in mortar applications is not recommended. If epoxy-coated reinforcement is desired, a preconstruction mockup should be shot and the effect of the mortar process on the epoxy coating should be examined by washing off the freshly applied mortar, coring, or by carefully dissecting the hardened shotcrete and examining the epoxy coating.

23.3.6.4. Fiber-Reinforced Shotcrete

Steel fibers between 13 and 40 mm long with dosage rates up to two percent (2%) by volume of the mortar can reduce crack propagation, increase flexural toughness, and improve ductility and impact resistance. Steel fiber dosages normally range between 20 and 70 kg/m$^3$; one percent (1%) by volume requires 78.5 kg/m$^3$. Steel fibers should conform to ASTM A 820.

Synthetic fibers for mortar are commonly polypropylene, either single filament or fibrillated, and are 25 to 50 mm long. Fibrillated fiber dosages of 1 to 3 kg/m$^3$ are common; one percent (1%) by volume requires 9 kg/m$^3$. Monofilament fibers are available and can be added at dosages of up to two percent (2%) volume of wet-mix shotcrete. Synthetic fibers should conform to ASTM C 1116.

23.3.6.5. Prestressing Steel

Prestressing steel should conform to ASTM standards.

23.3.6.6. Other Forms of Steel

Other steel bars and shapes used should conform to ACI 318, Chapter 3.
23.4. Shotcreting Processes

Shotcreting is classified according to the process used (wet-mix or dry-mix) and the size of aggregate used (coarse or fine). Refer to Table 23.1 for fine-aggregate grading (No. 1) and coarse-aggregate grading (No. 2).

23.4.1. Dry-Mix Process

The dry-mix process consists of five steps:

1. All ingredients, except water, are thoroughly mixed;
2. The cementitious-aggregate mixture is fed into a special mechanical feeder or gun called the delivery equipment;
3. The mixture is usually introduced into the delivery hose by a metering device such as a feed wheel, rotor, or feed bowl. Some equipment use air pressure alone (orifice feed) to deliver the material into the hoses;
4. The material is carried by compressed air through the delivery hose to a nozzle body. The nozzle body is fitted inside with a water ring, through which water is introduced under pressure and thoroughly mixed with the other ingredients; and
5. The material is jetted from the nozzle at high velocity onto the surface to be shotcreted.

23.4.2. Wet-Mix Process

The wet-mix process consists of five steps:

1. All ingredients, including mixing water, are thoroughly mixed;
2. The mortar or concrete is introduced into the chamber of the delivery equipment;
3. The mixture is metered into the delivery hose and moved by positive displacement or conveyed by compressed air to a nozzle;
4. Compressed air is injected at the nozzle to increase velocity and improve the shooting pattern; and
5. The mortar or concrete is jetted from the nozzle at high velocity onto the surface to be shotcreted.

23.4.3. Comparison of the Processes

Either process can produce shotcrete suitable for normal construction requirements. Differences in capital and maintenance cost of equipment, operational features, suitability of available aggregate, and placement characteristics, however, may make one or the other more attractive for a particular application. Table 23.2 gives differences in operational features and other properties that may merit consideration.
Table 23.2: Comparison of Dry-Mix and Wet-Mix Processes

<table>
<thead>
<tr>
<th>Dry-Mix Process</th>
<th>Wet-Mix Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Instantaneous control over mixing water and consistency of the mixture at the nozzle to meet variable field conditions.</td>
<td>• Mixing water is controlled at the mixing equipment and can be accurately measured.</td>
</tr>
<tr>
<td>• Better suited for placing mixtures containing lightweight aggregates or refractory materials.</td>
<td>• Better assurance that the mixing water is thoroughly mixed with other ingredients.</td>
</tr>
<tr>
<td>• Capable of being transported longer distances.</td>
<td>• Less dust and cementitious materials lost during the shooting operation.</td>
</tr>
<tr>
<td>• Delivery hoses are easier to move.</td>
<td>• Normally has lower rebound, resulting in less waste.</td>
</tr>
<tr>
<td>• Lower volume per hose size.</td>
<td>• Higher volume per hose size.</td>
</tr>
</tbody>
</table>

23.5. Preliminary Procedures

23.5.1. General

The quality of a mortar application is dependent on the care taken in the preparation and maintenance of the surface before and during mortar application.

Attention shall be given to the condition and integrity of the receiving surface against which the mortar will be placed.

23.5.2. Surface Preparation

The amount of surface preparation required depends on the condition and nature of the surface against which shotcrete is to be placed and the desired end product. If the receiving surface is only a form and bond is not important, little, if any, preparation is needed. Because the shotcrete impact will cause loose material from the substrate to combine with the shotcrete, the first few inches of the in-place shotcrete will have loose material mixed into the in-place shotcrete. The following sections discuss special requirements of surface preparation for earth, steel, concrete, masonry, rock, and wood surfaces.

23.5.2.1. Steel Surfaces

Before shotcrete is applied over steel surfaces, all unacceptable amounts (to be judged by designer) of loose mill scale, rust, oil, paint, or other contaminants as described below should be removed by sandblasting or other methods. Refer to ACI 546R, SSPC-SP13/ NACE No. 6 and ICRI Technical Guideline No. 03737, “Guide for the Preparation of Concrete Surfaces for Repair Using Hydrodemolition Methods.”

If high-pressure water blasting is used, all freestanding water should be removed before applying shotcrete.

23.5.2.2. Concrete Surfaces

All spalled, severely cracked, deteriorated, loose, and unsound concrete shall be completely removed from the existing concrete surface by chipping, scarifying, sandblasting, water blasting, or other suitable mechanical methods. Refer to SSPC-SP13/NACE No. 6 for more information. Any concrete that is contaminated by chemicals or oils should be removed. Abrupt changes in the repair thickness should be
avoided. The perimeter of the repair may be saw-cut to a depth compatible with the depth and type of repair. Edges that are chipped should taper at approximately 45 degrees toward the center of the repair area. Feather edging should be avoided.

If pneumatic or electric impact tools are used for removing the concrete, the tools should be chosen to minimize damage to sound concrete that may be underlied or adjacent to deteriorated material. Where mortar is to be placed against a smooth concrete surface, the surface should be roughened by sandblasting, bush hammering, or by other suitable mechanical means.

Following initial removal, the surface of the existing concrete should be inspected to see that only sound material remains. This is particularly critical if mechanical impact removal, such as bush hammering, has been used because there is a possibility of residual fractured fragments on the surface. Sounding with a hammer has long been used as a method of inspection to check for delaminations and hollows; however, this method may only be capable of detecting them within 100 to 150 mm of the surface.

When surface preparation is completed, all repair areas should be thoroughly cleaned by sandblasting, hydromilling, or other methods to remove any traces of dirt, grease, fractured concrete, oil, or other substances that could interfere with the bond of the newly placed mortar. If sandblasting is used, the excess sand and loose debris should be vacuumed or blown from the surface with compressed air, water, or both. Particular care should be taken to remove such debris around anchors or reinforcing rods.

Adequate prewetting of the concrete substrate should be done before shotcreting. Concrete substrates should be in a saturated surface-dry (SSD) condition immediately before mortar application for maximum adhesion.

23.5.2.3. Masonry Surfaces

Masonry surfaces require preparation similar to that of concrete surfaces; however, preventing absorption of water from the mortar into the underlying masonry is critical. Severe cracking of the mortar can result if this is not done. One method used to prevent this problem is dampening the masonry surface before applying mortar.

23.5.2.4. Rock Surfaces

Loose material, debris, chips, mud, dirt, or other foreign matter should be removed to ensure a strong bond between the rock and the mortar, if desired.

There may be situations, however, where complete removal may be hazardous or inadvisable, such as in some underground applications where early support is required. In such cases the Contractor in consultation with the Engineer must provide alternatives to mitigate the impeding situation.

23.5.2.5. Earth Surfaces

Proper preparation and compaction of the earth is essential. The earth surface is then trimmed to line and grade to provide adequate support and to aid in obtaining the designed thickness of the mortar.

The shotcreter should not place mortar on an earth surface that is frozen or spongy. To prevent excessive absorption of mixing water from the mortar, the following techniques are available:
• Prewet the earth surface by spraying water before applying the mortar. The amount of predampening will depend on the absorption qualities of the earth; however, puddling, ponding, or leaving freestanding water should be avoided; and

• A moisture barrier system may be installed that will inhibit the movement of moisture from the newly placed mortar into the earth. If sheet material is used, care should be taken to avoid wrinkling or folding to eliminate the formation of voids beneath the moisture barrier or creation of a thin layer of mortar.

To prevent wash-out of freshly placed mortar due to water seepage, the seepage should be controlled using conduits to channel the water. After water seepage is controlled, the mortar can then be placed and when the mortar has set, the water conduits can be hand-plugged using flash-setting cement.

23.5.2.6. Wood Forms

If forms are to be removed after use, a form-release agent should be applied to the form to prevent absorption of moisture and to inhibit bond between mortar and the form. Shotcreting against a form with a form-release agent may cause the agent to mix with the mortar. Consequently, the type of form-release agent should be carefully selected so as not to damage the surface skin of mortar. Otherwise, form requirements are similar to conventional concrete.

23.5.3. Anchors

Special devices are used in mortar work to anchor, support, or space the reinforcement. Some of the factors involved in determining the type, size, and spacing of these devices are: the type of application; its design; the mortar thickness; the nature of the original surface; and the type, weight, and geometry of the reinforcement. The maximum recommended spacing of anchors for most applications is 0.9 m on-centers-both-ways for horizontal surfaces, 0.6 m on-centers-both-ways for vertical and inclined surfaces, and 0.45 m on-centersboth-ways for overhead surfaces. If special conditions exist, the design of the anchor spacing and size should be checked for sufficiency in pullout and shear. Anchors or spacers for reinforcement should be located to provide sufficient clearance around the reinforcement, permit proper cover, and complete encasement with sound mortar. Special bowtie connectors are sometimes used with fiber-reinforced mortars to provide mechanical connection to the anchors.

23.5.3.1. Anchoring to Steel

Reinforcement can be attached to steel surfaces using mechanical clips, blank nuts welded to the steel, stud-welded devices, slab bolsters, or selftapping screws; by direct attachment; or by any manner that does not compromise the integrity of the structural member.

Clips and bolsters are only used to directly attach mesh to steel. Studs or nuts can be used to attach reinforcing bars or mesh. Drilling holes through structural members to facilitate the anchoring of reinforcement should be avoided. Consult the structural engineer before drilling into structural members or before welding reinforcing steel.

23.5.3.2. Anchoring to Concrete, Masonry, or Rock

Reinforcement can be attached to concrete, masonry, and rock surfaces using expansion anchor bolts, steel dowels, self-drilling fasteners, and expansion shields. The choice depends to a large degree on the application, type of specified reinforcement, position of work, number and size of anchors, and cost. The manufacturer’s
recommendations for size, depth of hole, and safe-working loads in shear and pullout should be explicitly followed.

Expansion anchor bolts are the most commonly used concrete anchors. They are available straight and threaded with a nut at the exposed end or without threads with a hooked or L-shaped exposed end. Both styles have some type of expanding sleeve or wedge on the embedded end to provide positive locking action in a predrilled hole. These anchors come in variable lengths so they can be adapted to mortar from 40 to 150 mm thick.

Self-drilling fasteners and expansion shields may be used and are useful for 150 mm and thicker layers, up nonuniform mortar sections, and where multiple layers of reinforcement are specified.

Steel dowels or reinforcing bars are used in structural mortar applications when sections are 150 mm or thicker, and heavy cages of reinforcing bars have to be supported and anchored. They are also used for anchoring mortar to rock. They should be set sufficiently deep to meet pullout criteria and installed using a nonshrink cementitious grout, epoxy, or polyester resin.

23.5.3.3. Anchoring to Wood

Reinforcement may be attached to wood surfaces using individual bar chairs, slab bolsters (continuous chairs), or nails. They should be positioned to provide proper cover and encasement by the mortar. Bolster legs should be trimmed off when they are adjacent or parallel to reinforcement. If the wood surface is a removable form, nails should not be used and the chairs and bolsters should be plastic-tipped to eliminate rust on the formed surface.

Reinforcing bars or individual wires in mesh should not coincide with the longitudinal wire of a slab bolster.

23.5.4. Protection of Adjacent Surfaces

Rebound, overspray, and dust resulting from the mortar application can contaminate adjacent structures, equipment, and grounds. This problem is especially aggravated on windy days. Therefore, it is important to evaluate the effect of the mortar application on adjacent surfaces and make the necessary arrangements to protect them. Ideally, isolate the mortar operation from areas or surfaces needing protection. Although this is not always possible, protection can take the form of a cover, masking materials, or temporary protective coatings. Covers may include plywood or similar materials, polyethylene film, or drop cloths. Masking materials are usually used in conjunction with the above materials. Temporary protective coatings include grease, diesel oil, and other materials that can be removed without too much difficulty.

If none of the above are practical, adjacent surfaces should be cleaned and washed before the rebound and overspray hardens. The protection of adjacent surfaces should include concern for the buildup of overspray, rebound, and dust on surfaces that receive mortar. If these materials are allowed to build up, they will cause low mortar strength and interfere with bonding.
23.6. Proportioning and Preconstruction Testing

23.6.1. Proportioning of Shotcrete Mixture

23.6.2. General

It is not practical to conduct laboratory trial mixtures for the dry-mix process, and there are also problems in duplicating as-shot conditions for the wet-mix process. Therefore, field trials and preconstruction testing, as described in Article 23.6.3 “Preconstruction Testing” should be used for qualifying mixture proportions.

The mixture proportions should be designed to produce sample strengths higher than the design strength. Refer to ACI 214R for guidance.

23.6.2.1. Wet-Mix Process

A typical wet-mix shotcrete mixture proportion will have 390 to 450 kg of cement, cement plus fly ash, or other pozzolan per cubic meter of concrete. Aggregate will consist of twenty to thirty percent (20 to 30%) pea gravel, 13 mm maximum, seventy to eighty percent (70 to 80%) concrete sand or sands with a combined sand fineness modulus of 2.5 to 2.9, a water-reducing admixture, and a water content that will yield a slump of 40 to 75 mm.

The concrete should be proportioned so that it is pumpable with at least fifty to thirty percent (15 to 30%) fine aggregate passing the No. 100 (0.15 mm) screen and a maximum nominal-size aggregate less than 1/3 the diameter of the material hose.

The slump of the wet-mix process shotcrete should generally be the minimum that can be handled by the pump. Excess slump results in a weaker mortar and sloughing when the mortar is placed on vertical or overhead surfaces. A mixture that is too stiff may be difficult to pump and shoot and may not fully encapsulate reinforcement.

For durability and pumppability, water cement ratio (w/c) for normal wet-mix mortar typically ranges from 0.4 to 0.5 without admixtures. Lower w/c are possible with the use of water-reducing admixtures (all types).

Wet-mix shotcrete should be air-entrained when the shotcrete will be subjected to freezing and thawing in saturated conditions. A minimum total air content of six percent (6%) in the concrete before pumping is generally desirable.

23.6.2.2. Dry-Mix Process

1. Aggregate Proportion

Aggregates should be a blend of sizes as required to produce a combined grading within the limits of Table 23.1. The particle-size distribution of aggregates in place will be markedly finer than when batched because the larger particles have proportionally larger rebound loss. Rebound losses can cause an approximate thirty percent (30%) change in the cement-to-aggregate ratio. A mixture of 1:3 entering a gun can result in a 1:2 mixture in place.

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1 Pea gravel: Gravel consisting of pieces the size of peas hence the name.
2. Mixture Proportions

There is no recognized rational method of proportioning dry-mix shotcrete for strength. Applicators, who use the same consistent sources of materials and can provide adequate proportioning data from previous experience, are typically permitted to use proven mixtures. This approach is appropriate for many small projects where the cost of preconstruction testing is prohibitive. Preconstruction testing is required if previous data are not available, properties other than strength affect the design criteria, or if design requirements vary from one portion of the work to another. Preconstruction testing to determine mixture proportions is also advisable if there is some question as to the gradation or quality of the aggregate and the effect of the amount and spacing of the reinforcing steel.

It is possible to produce dry-mix shotcrete of extremely high strength if high cement contents and quality aggregates are used and if a high degree of in-place compaction is achieved. Compressive strengths as high as 80 MPa have been reported for trial mixture panels, and 70 MPa strengths are commonly quoted in the literature.

Strengths higher than 35 MPa, however, should not be specified except in carefully controlled projects where adequate research into the potential performance of local materials has been performed.

For coarse-aggregate shotcrete mixtures, Table 23.3 illustrates some typical data on the effect of as-batched cement content on strength of typical dry-mix shotcrete mixtures.

Field trials are required to determine the final cement content. The method of evaluating the in-place cement content and strength of shotcrete is detailed in ACI 506.4R.

Table 23.3: Strength versus Cement Content

<table>
<thead>
<tr>
<th>Compressive Strength at 28-day, (MPa)</th>
<th>Cement Content as Batched, (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>295 - 385</td>
</tr>
<tr>
<td>28</td>
<td>325 - 415</td>
</tr>
<tr>
<td>35</td>
<td>385 - 505</td>
</tr>
</tbody>
</table>

23.6.3. Preconstruction Testing

For preconstruction studies, shooting test panels that simulate actual job conditions, such as reinforcing bar congestion, provides a sufficiently reliable indication of the quality to be expected in the structure.

23.6.3.1. Field trials

A panel is fabricated by shooting onto a back form of heavy plywood or steel plate in accordance with ASTM C 1140. A separate panel should be fabricated for each mixture proportion being considered, and also for each shooting position to be encountered in the structure such as horizontal, vertical, or overhead. Results of previous tests with similar materials, mixture proportions and applications may be acceptable to the engineer instead of preconstruction testing.

Separate test panels should be fabricated for mixture proportion evaluation and for nozzle operator qualification. The mixture proportion test panels should be 610x610x89 mm with flared sides and no reinforcement. The nozzle operator qualification test panel should be large enough to simulate the actual project conditions.
with a minimum size of 760×760×75 mm and should be reinforced to simulate the size
and complexity of the reinforcement to be shot on the project.

23.6.3.2. Coring

Both types of test panels should be cored or sawn to obtain 75 mm diameter cores
or 75 mm cubes. The unreinforced cores or cubes should be tested for compressive
strength. Cube strengths may be reported as determined or converted to equivalent
cylinder strengths by multiplying by 0.85. ACI 506.2 lists requirements for testing.

The cut surfaces of the specimens should also be carefully examined, and additional
surfaces should be exposed by sawing or breaking the panel when necessary to check
the soundness and uniformity of the material. All cut and broken surfaces should be
dense and free from laminations, voids, and sand pockets.

The procedures described previously should determine the optimum proportions to
consistently achieve the result specified. Once the mixture proportions have been
established by the Engineer, they should be monitored. It may be permissible, however,
to make the test panels concurrent with the start of construction, or cores can possibly
be taken from the first shotcrete placed in the structure.

On relatively small jobs and where the materials, mixture proportions, equipment,
and personnel have given satisfactory results on previous work, preconstruction studies
may not be justified.

23.6.3.3. Testing of Cores

The cores shall be soaked in water for 40 hours immediately before testing. Three
cores from each test panel shall be tested four days after the field trial. The remaining
three cores shall be tested 28 days after the field trial. Tests shall be performed
according to AASHTO T 23 (ASTM C31).

Tests for modulus of rupture, flexural toughness of fiber reinforced shotcrete,
absorption, drying shrinkage, resistance to freezing and thawing, and other properties
may also be conducted if required, using appropriate specimens cored or sawed from
the panel. All tests should meet the requirements of ASTM E 329.

23.6.3.4. Mix Design Acceptance

The test data and a visual description of each core shall be submitted to the
Engineer. Details concerning presence of voids, sand pockets, lamination, and other
inadequacies shall be included. Acceptance of the nozzlemen and mix design will be
based on preconstruction field trials and test results. The visual quality of the cores
shall not be lower than grade 2 according to pneumatically applied mortar grading
requirements of ACI 506.2.

Field quality control test reports shall be submitted within two working days of
performing the tests.

23.7. Placement of Pneumatically Applied Mortar

23.7.1. Placement of Reinforcement

Reinforcing steel, when required, shall be installed in conformance with the
requirements of Section 11, "Reinforcing Steel."
Placement of Pneumatically Applied Mortar

Section 23: Pneumatically Applied Mortar

Placement of Pneumatically Applied Mortar

(Shotcrete)

Reinforcement in new construction shall be placed as specified in the contract documents and secured to ensure that no displacement results from impact of the pneumatically placed mortar during application.

For repair work, the reinforcing steel shall be supported by anchor studs installed in the existing masonry, except where existing reinforcing steel in the repair area is considered by the Engineer to be satisfactory for this purpose. Anchors shall be spaced no more than 300 mm, center-to-center, on overhead surfaces; 450 mm, center-to-center, on vertical surfaces; and 900 mm, center-to-center, on top horizontal surfaces. At least three (3) anchors shall be used in each individual patch area.

The Engineer shall be notified in advance of the date when installation of anchor studs shall begin. The locations of the studs shall be such that damage will not occur to prestressing tendons or conduits embedded in the concrete.

Unless otherwise specified in the contract documents, for repair work, all areas where the thickness of the mortar exceeds 38 mm shall be reinforced with a single layer of either 2×(50 mm ×50 mm) or (75 mm ×75 mm) welded wire fabric. For areas where the thickness of the mortar exceeds 100 mm, a single layer of wire fabric shall be used to reinforce each 100 mm thickness of patch or fractional part thereof. All fabric shall be placed parallel to the proposed finished surface. Before the succeeding layer of fabric is installed, each layer of fabric shall be completely encased in mortar that has taken its initial set. Fabric supported adjacent to the prepared masonry surface shall be no closer than 12 mm to said surface. Fabric shall be carefully prebent before installation to fit around corners and into re-entrant angles, and shall in no case be sprung into place.

All steel items, including anchors, reinforcing bars, and wire fabric, shall be no closer than 25 mm to the finished surface of the mortar.

23.7.2. Placement of Mortar

Only experienced personnel shall be employed, and satisfactory evidence of such experience shall be furnished when requested by the Engineer.

The mortar shall be applied by pneumatic equipment that sprays the mix onto the prepared surface at required high velocity as needed to produce a compacted, dense, homogeneous mass. The air compressor and delivery hose lines shall be of adequate capacity and size to provide a minimum pressure of 0.24 MPa at the nozzle for 25 mm nozzles and proportionally greater for larger nozzles. The velocity of the material as it leaves the nozzle must be maintained uniform at a rate determined for the given job conditions to produce minimum rebound.

Water which is added at the nozzle shall be supplied at a uniform pressure of not less than 0.1 MPa greater than the air pressure at the nozzle.

The mortar shall be applied as dry as practicable to prevent shrinkage cracking. Shooting strips shall be employed to ensure square corners, straight lines, and a plane surface of mortar, except as otherwise specified in the contract documents or approved by the Engineer. They shall be so placed as to keep the trapping of rebound at a minimum. At the end of each day's work, or similar stopping periods requiring construction joints, the mortar shall be sloped off to a thin edge. Before placing an adjacent section, construction joints shall be thoroughly cleaned and wetted as required under Article [23.5.2], "Surface Preparation." In shooting all surfaces, the stream of flowing material from the nozzle shall impinge as nearly as possible at right angles to
the surface being covered, and the nozzle shall be held 0.6 to 1.2 m from the working surface.

A sufficient number of mortar coats shall be applied to obtain the required thickness. On vertical and overhead surfaces, the thickness of each coat shall be not greater than 25 mm, except as approved by the Engineer, and shall be so placed that it will neither sag nor decrease the bond of the preceding coat. The time interval between successive layers in sloping, vertical, or overhanging work shall be sufficient to allow initial but not final set to develop. At the time the initial set is developing, the surface shall be cleaned to remove the thin film of laitance in order to provide for a bond with succeeding applications.

Rebound or accumulated loose sand shall be removed from the surface to be covered prior to placing of the original or succeeding layers of mortar and shall not be embedded in the work.

Materials that have been mixed for more than 45 min and have not been incorporated in the work shall not be used, unless otherwise permitted by the Engineer.

After curing and before final acceptance, all repaired areas shall be sounded. All unsound and cracked areas shall be removed and replaced.

23.7.3. Finishing

After mortar has been placed to the desired thickness, all high spots shall be cut off with a sharp trowel, or screeded to a true plane as determined by shooting strips or by the original masonry surface, or as directed. Cutting screeds, where used, shall be lightly applied to all surfaces so as not to disturb the mortar for an appreciable depth, and they shall be worked in an upward direction when applied on vertical surfaces. Unless otherwise specified in the contract documents, the finished mortar surface shall be given a final flash coat of about 3 mm of mortar. Special care shall be taken to obtain a uniform appearance on all exposed surfaces.

23.7.4. Weather Limitations

23.7.4.1. Hot-Weather Shotcreting

With dry-mix process, the time from mixing to shooting a mixture should not exceed 15 minutes; otherwise, undesirable decreases in strength due to prehydration can occur.

With wet-mix process, the undesirable effects are similar to those encountered with normal pumped concrete. The problems include increased water demand, increased rate of slump loss, increased rate of set, and difficulty in regulating entrained air content. There should be procedures to handle these problems to ensure a satisfactory mortar installation.

Once the mortar is in place, placing, finishing and curing procedures are similar to those for concrete.

Scree ding and finishing operations should proceed as rapidly as the shotcrete conditions allow. Curing should start promptly after finishing is completed. Ideally, the temperature of the mortar should be maintained between ten degrees Celsius (10°C) and thirty-eight degree Celsius (38°C) during all phases of the installation procedure.
23.7.4.2. Cold-Weather Shotcreting

The shotcreter should not place shotcrete on frozen surfaces. This and other precautions used to protect concrete from freezing should also be used for protecting mortar.

Mortar has a greater heat of hydration than conventional cast-in-place concrete because of its higher cement factor that aids in resisting freezing, but it is placed in thin layers with large surface areas providing for rapid loss of heat that partially counterbalances the heat of hydration benefits.

Shooting can be allowed if the temperature is at least five degrees Celsius (5°C) and rising and discontinued at five degrees Celsius (5°C) and falling.

Once the mortar is in place and finished, it should be cured and protected from freezing until it reaches sufficient strength. Water curing in a freezing environment is not recommended. The temperature during curing should be maintained above five degrees Celsius (5°C). When mortar will be placed under cold-weather conditions, a plan should be developed outlining procedures for surface preparation, mortar placement, curing, and protection.

23.8. Curing and Protecting

Mortar should be properly cured so that its potential strength and durability are fully developed. This is particularly true for the thin sections and low w/c associated with mortar. The best method for curing is to keep the shotcrete wet continuously for 7 days while maintaining a temperature over five degrees Celsius (5°C). The temperature of the curing water should not be lower than ten degrees Celsius (10°C) cooler than the shotcrete surface at the time the water and shotcrete come in contact. Covering mortar with sheet materials (ASTM C 171) is another method used to cure shotcrete.

Curing compounds are satisfactory if drying conditions are not severe, no additional shotcrete or paint is to be applied, and the resulting appearance is acceptable. Where the surface has a natural gun or flash finish, the liquid membrane-curing compound (ASTM C 1315) should be applied at a rate twice that recommended by the compound manufacturer.

Natural curing may be allowed if the relative humidity is continuously maintained at or above eighty-five percent (85%). More detailed information on curing can be found in ACI 308.1 and ACI 506.2. The rapid drying of shotcrete at the end of the curing period shall be avoided.

23.9. Quality Control

23.9.1. Materials

The source of all materials should be submitted to the design authority for approval. If the source is approved, the material should either be certified by the supplier that it meets specifications or be tested on a regular basis. The project size and character would dictate which procedure is suitable.

Mixture proportions may be detailed in the specification or may be selected by the contractor to produce a specified compressive strength or other properties. In either case, a design or proof mixture must be made and tested. Delivery, handling, and storage of the materials should be checked for compliance with the specifications. For supplemental information on specific details for quality control of shotcrete materials, refer to ACI 506.2 and Article 23.3, “Materials”.

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23.9.2. Placement Techniques

One of the most important factors that should be considered in shotcrete installation is placement technique. If quality control is excellent in all other aspects of the shotcrete application but placement is questionable, an unsatisfactory product may result. The procedures and techniques described in other portions of this guide should be followed closely because they represent good shotcrete practice.

23.9.3. Inspection

A knowledgeable, thorough, and qualified inspector is a necessary requirement for implementing quality-assurance procedures. The inspector should be familiar with plans, specifications, and applicable standards. The inspector should understand all facets of the shotcrete process, especially the installation technique referred to in Article 23.7, “Placement of Pneumatically Applied Mortar”. The inspector should continuously inspect the work, paying attention to materials, forms, reinforcement, equipment, placement, finishing, curing, and protection of the finished product. The inspector also is responsible for the field testing as outlined in the following section.

23.9.4. Testing Procedures

An important aspect of quality assurance is the physical testing of the mortar before, during, and after placement. ACI 506.2 describes the procedures to be followed in preconstruction and construction testing. The testing and/or inspection should meet the requirements of ASTM E 329.

Normal testing ages for compressive strength are 7 and 28 days; however, shorter periods may be required for particular applications or conditions. Testing is usually done once a day or every 40 m³ whichever is greater. Sampling and testing, however, should be varied according to the size and complexity of the project. Sampling should be done in accordance with ASTM C 1385. Making extra cylinders or panels is sometimes done if testing results vary.

Other testing may include tests for water absorption, drying shrinkage, and resistance to freezing-and-thawing cycles. Fiber-reinforced mortar may require fiber washout tests or flexural toughness testing according to ASTM C 1018.

Acceptance of mortar should be based on results obtained from drilled cores or sawed cubes (ASTM C 42). The use of data from nondestructive testing devices, such as impact hammers or probes (ASTM C 805, ASTM C 803), ultrasonic equipment (ASTM C 597), and pull-out devices (ASTM C 900) may be useful in determining the uniformity and quality of the in-place shotcrete. These tests, however, may not provide reliable values for compressive strength. Refer to ACI 228.2R for additional information on nondestructive testing.

Core grading is a method used to evaluate encasement of reinforcement. Core grading is only used for nozzle operator evaluation and is done in accordance with ACI CP-60. Core grading should not be used to evaluate structures.

23.10. Measurement and Payment

23.10.1. Measurement

The quantity of pneumatically applied mortar shall be measured either by the square meter or by the cubic meter as specified in the contract documents.
Square-meter measurements shall be based on measurements of the surface area of acceptable mortar placed in the work made along the plane or curve of each surface. Cubic meter measurement shall be based on the dimensions of such work shown in the contract documents or ordered by the Engineer.

### 23.10.2. Payment

Pneumatically applied mortar shall be paid for by the unit contract price specified. Such payment shall be considered to be full compensation for the cost of furnishing all labor, materials, equipment, and incidentals, and for doing all work involved in preparing the surface and installing the mortar, reinforcing steel, anchor studs, headers, joint fillers, and other items as specified in the contract documents.

Payment will be made as indicated in Table 23.4. And the quality control requirements for pneumatically applied mortar are shown in Table 23.5.

#### Table 23.4: Pneumatically Applied Mortar Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.4.1</td>
<td>Shotcrete</td>
<td>Square or Cubic Meter</td>
</tr>
</tbody>
</table>

#### Table 23.5: Quality Control Requirements For Pneumatically Applied Mortar

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Preparation</td>
<td>Earth, The area shall be accurately graded and thoroughly compacted</td>
<td>Surveying and compaction test</td>
<td>In situ and laboratory</td>
<td>As directed by the engineer</td>
<td>Article 23.5.2.5</td>
</tr>
<tr>
<td></td>
<td>Wood Forms, The Case of temporary structures</td>
<td>Conformity and checkup</td>
<td>In situ</td>
<td>-----</td>
<td>Article 23.5.2.6 and Section 6, &quot;Temporary Structures&quot;</td>
</tr>
<tr>
<td></td>
<td>Concrete or Rock, To indicate the thickness of the pneumatically applied mortar layers</td>
<td>Depth gauges shall be installed on 2 meters centers longitudinally and transversely</td>
<td>In situ</td>
<td>-----</td>
<td>Article 23.5.2.2</td>
</tr>
<tr>
<td>Placement of Reinforcement</td>
<td>All steel items, including anchors, reinforcing bars, and wire fabric, shall be no closer than 25 mm to the finished surface of the mortar</td>
<td>Conformity and checkup and measurement</td>
<td>In situ</td>
<td>-----</td>
<td>Article 23.7.1 and the requirements of Section 11, &quot;Reinforcing Steel.&quot;</td>
</tr>
<tr>
<td>Placement of Mortar</td>
<td>High velocity needed to produce a compacted, the nozzle shall be held 0.6 to 1.2 m from the working surface</td>
<td>Visual inspection and measurement</td>
<td>In situ</td>
<td>-----</td>
<td>Article 23.7.2</td>
</tr>
</tbody>
</table>
### Table 23.6: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>As specified</td>
<td>AASHTO T 23</td>
<td>ASTM C31</td>
<td>Standard Practice for Making and Curing Concrete Test Specimens in the Field</td>
</tr>
<tr>
<td>the average core compressive strength ≥ specified 28 day compressive strength minus (3.5 Mpa)</td>
<td>AASHTO T 24</td>
<td>ASTM C42</td>
<td>Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM C 150</td>
<td></td>
<td>Standard Specification for Portland Cement</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM C 595</td>
<td></td>
<td>Standard Specification for Blended Hydraulic Cements</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM C 1157</td>
<td></td>
<td>Standard Performance Specification for Hydraulic Cement</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM C 33</td>
<td></td>
<td>Standard Specification for Concrete Aggregates</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM C 330</td>
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### Section 23: Pneumatically Applied Mortar (Shotcrete)

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<td>ASTM C 900 Standard Test Method for Pullout Strength of Hardened Concrete</td>
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#### 23.11. References

- **ACI 506.1** "State of the Art Report on Fiber Reinforced Shotcrete".
- **ACI 506.2** "Specifications for Proportioning Application of Shotcrete".
- **AASHTO LRFD Construction Specifications Second Edition 2004- Sec. 24.**
- **FHWA** “Standard Specifications For Construction Of Roads And Bridges On Federal Highway Projects Fp-03-Metric Units. Sec. 566.
- **MOMRA: Kingdom of Saudi Arabia Ministry of Municipal & Rural Affairs Deputy Ministry for Technical Affairs – "Bridges Design Specifications (MA-100-D-V1/2 & V2/2)" 2013.**
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SECTION 24. TUNNEL CONSTRUCTION

24.1. Scope

24.1.1. Description

This work shall consist of requirements for underground works including tunnels, shafts, adits, caverns, chambers and portals.

This work shall also consist of furnishing cold-formed steel tunnel liner plates or pre-cast concrete plates, conforming to these Specifications and of the sizes and dimensions required in the contract documents, and installing such plates at the locations specified in the contract documents or by the Engineer and in conformity with the lines and grades established or by the Engineer. The completed liner shall consist of a series of liner plates assembled with staggered longitudinal joints.

Steel tunnel liner plates should be of a type that is commercially available. Pre-cast concrete tunnel liner plates shall be such that their size and shape suits the method and equipment being used to install them.

24.1.2. Definitions

The following terms shall have the meanings hereby assigned to them:

- **Clearance Line**
  The line within which no point of rock in completed excavation shall project. Where no clearance line is shown on the Drawings it shall be taken as the outer limit of the minimum thickness of concrete shown.

- **Temporary support**
  Steel ribs, steel lagging, sprayed concrete, concrete, reinforcement, rock bolts or other means used to prevent ground material from falling or moving into the excavated area. It shall not include permanent lining ordered by the Engineer but shall be incorporated in the permanent support where ordered by the Engineer.

- **RMR**
  Rock Mass Rating developed by Bieniawky in 1973, also called Geomechanics Classification

- **Adits**
  Small size tunnel excavated for investigation of the rock condition before design of the tunnel support. It may be open or close at the end. Generally it is horizontal or inclined

- **Shafts**
  A vertical Adit generally used for access.

- **CIRIA**
  Construction Industries Research and Information Association (British)

- **NATM**
  New Austrian Tunneling Method
24.2. Reference Standards

24.2.1. Standards

Unless otherwise specified, underground works shall comply with the following Reference Standards.

- **BS 5607:1998** Code of practice for safe use of explosive in the construction industry.
- **BS 6164:2001** Code of practice for safety in tunneling in the construction industry.
- **CIRIA Report 44** Medical code of practice for work in compressed air.

Other Reference Standards referred to in this Section include:

- **DIN-1045,1084** Proportioning of aggregate for obtaining specified crushing strength
- **ASTM C-150-04** Portland Cement
- **ASTM C192** Capping of concrete cubes for testing
- **DIN 1045** Statistical Analysis of Cube Test Results
- **ASTM C 243-85** For determining bleed in sand-cement mixture
- **BS 4483-A193** Steel mesh reinforcement

24.3. Submissions

24.3.1. Methods of Construction

The Contractor shall submit details of his proposed methods of tunnel and shafts excavation and support, including:

- The equipment for excavation and spoil removal in rock and soft ground.
- The equipment for grouting.
- The number, sitting and sizing of any construction Adits, passing bays and safety niches.
- Methods of temporary support including rock-bolting, shotcreting and mesh.
- Proposals for steel ribs to shafts and tunnels.
- Methods and instruments to be employed for making convergence measurements.
- The methods of dealing with water, ventilation and illumination.
- Safety measures in underground works.

The contractor shall submit details of his proposed methods of constructing permanent linings for tunnels and shafts, including:

- Methods of constructing bolted precast concrete tunnel lining including cavity grouting.
- Methods of constructing in situ concrete linings including contact grouting.
- Methods of installing and concreting steel tunnel linings.
24.3.2. Design Calculations

The Contractor shall submit his design calculations for the bolted precast concrete tunnel lining.

24.4. General Requirements

24.4.1. General

The Contractor shall be responsible for all methods of working in underground works, including the design, provision and erection of all things necessary to safeguard the works and the workmen. In particular, the Contractor shall be responsible for the support of all excavation in underground works during construction, which shall include making good after falls.

All procedures necessary to safeguard the works and workmen, except for any emergency measures that may have to be taken by the Contractor to ensure safety, shall be subject to the prior approval of the Engineer, but such approval shall not relieve the Contractor of any of his responsibilities.

Except otherwise required, tunnels in soft ground shall be straight or, in order to accomplish changes in alignment, shall lie on horizontal and vertical circular curves of about 300 meter radius. Curves may be omitted where a change in alignment occurs at a shaft.

24.4.2. Safety General

The Contractor shall provide all safety measures to avoid any danger to personal, equipment installation and the structure itself not only in the case of obvious danger, but also in the case of merely suspended danger. The contractor shall immediately take adequate safety measures.

The Contractor shall be fully conversant and comply with BS 6164:2001 and its recommendations.

In case of difficult rock conditions as weak rock fault zones, karstic areas with karstic water, gas etc, the contractor shall provide at his expense, core drilling ahead to determine difficulties in advance and to provide all corresponding safety measures.

The local safeguarding arrangements required and made by the Contractor are subject to approval by the Engineer. In the event of rock falls owing to unfavorable bedding jointing local faults, etc., work shall be carried out with particular care and protective safety measures.

When excavation is being executed through zones of earth, earth/rock sequence, weak or weathered rock or any other zones where the rock is unstable, they shall be stabilized during construction or shall be supported permanently by means of steel supports with permanent or temporary lines or lagging placed as required by local conditions with the prior approval or order of the engineer. When excavation is being made through sound and relatively unaltered rock, support by means of shotcrete, steel support or rock bolts shall be required when the structural characteristics of the rock may otherwise cause dangers conditions. These protective measures shall be installed in such a way that they allow their inspection easily and any time. All safety measures and requirements related to the construction activities and those described hereunder shall be obligatory for the contractor in all respects.

The safety of underground Excavations shall, at all times, be the responsibility of the contractor, as well as the adoption and fulfilling of all necessary measures to protect
the personal engaged in underground work from cave-ins, harmful gases or vapors, explosions, intoxications, electric discharges, floods and all other accidents of probable occurrence in the construction of tunnels, slopes, shafts, etc. The Contractor shall take all precautions normally adopted for this type of work and those that the Engineer may deem necessary within the scope of the work. Lack of compliance with any safety measures shall be a cause for the Engineer to suspend the execution of the works until the causes that determined the suspension are remedied, and in such cases the Contractor shall have no right to claim for time extensions or extra cost. In particular such measures shall include the following:

a) Provision of proper site safety and emergency regulations and fire, gas and electric shock precautions.

b) Provision of a first aid box, approved equipment, and rescue facilities at each tunnel portal shaft.

c) Provision of a first aid post manned day and night by a trained nurse and served by a vehicle equipped as a field ambulance and having a day and night duty driver. The first aid post shall be in telephone communications with portals and shafts in their areas and shall have a telephone on the public network.

d) Safe storage, handling, and use of explosives, gases, fuels, and other dangerous goods.

e) Safe supporting of all excavations.

f) Provision of efficient safety helmets for all personal including authorised visitors to the site; provision where necessary of safety harnesses for personal including the Engineers Representative and his staff.

g) Control of water, including the provision of ample standby pumping and generating plants.

h) Provision of lighting to provide adequate illumination of the works, including spares and standby equipment.

i) Provision and maintenance of safe, sound rocks, slings, blocks, and other lifting tackle, each appliance having an up to date test certificate.

j) Provision of temporary ladders to all shafts, with landings at intervals not exceeding 6 m. Protection shall be so provided that neither persons using the ladders nor the ladders and their supports are subject to danger or risk of damage by the passage of skips and/or materials in the shaft.

k) Provision and maintenance of safe, sound hoists and cages for conveying personnel where necessary, each item having an up to date test certificate.

l) Provision of competent operators for control of lifting and hoisting equipment, with at least one banksman, the operators of shaft hoisting gear being in telephone communication with the bottom of the shaft.

m) Provision and maintenance of all temporary electrical installations to the standards prescribed in BS 6164.

n) Provision of notices, 1.5 m by 1.0 m in size written in bold letters, to be erected on existing footpaths and points of access likely to be used by the public to warn them of the existence of the works. These notices shall be in addition to any statutory requirements demanded of the Contractor.

The Contractor shall submit for the approval of the Engineer detail proposals under paragraph (a) above. When safety and emergency regulation have been approved, copies of the safety regulations shall be produced by the Contractor and distributed to all of his employees and staff and to the Engineer representative and his staff. Notices shall be displayed at all portals and shafts detailing emergency and rescue procedures.
The Contractor shall ensure that all personnel are conversant with the regulations and shall instantly dismiss and not re-employ any employee who commits a serious breach of the regulations.

24.4.3. Compressed Air Working

Where compressed air working is carried out the following requirements shall apply.

All the requirements and recommendations of CIRIA Report 44 “Medical code of practice for work in compressed air” shall be observed. Any requirements or recommendations which are not required by law to be undertaken, inspected or approved by a statutory authority or by a person appointed or approved thereby, shall be undertaken inspected, and require the approval of the Engineer or a person approved by him. Compressed air working shall not commence until the Contractor has submitted all details in accordance with the requirements of this Article and has received approval of them.

Standby plant shall be installed of sufficient capacity to maintain the required air pressure if, at any time, all or part of the main plant is out of use. The standby plant shall include a power source independent of the main source. The Contractor shall test all standby plant weekly by using it to supply to the work under normal working conditions.

The Contractor shall maintain such air pressures as may be necessary for the working, and shall provide facilities for varying the pressure accordingly.

In addition to the gauges required by CIRIA Report 44, further pressure gauges shall be installed in every working chamber showing the pressure in the chamber and in the adjacent manlock. Each manlock or decompression chamber shall be connected by telephone to the compressor house attendant post.

The air locks, medical locks, bulkheads, pipes and other apparatus to be used for compressed air working shall be capable of withstanding twice the maximum pressure to be used, after installation, but before work in compressed air is commenced, compressed air plant shall be given a 24-hour continuous running test at the normal operating pressure and shall operate to the Engineer’s satisfaction for this period. Each air receiver shall be fitted with a safety valve, which shall be set to blow at a pressure to be agreed with the Engineer.

24.4.4. Explosives

The transportation, handling and storage of explosives shall comply with the requirements of Kingdom of Saudi Arabia (KSA) regulations. All materials have to be stored at a safe place in a specially designed shelter. The design drawings of the shelter as well as the completed structures must be approved by the Inspector of Explosives in relevant ministry.

The contractor shall be fully conversant and comply with the relevant sections of all regulations relating to the storage, issue, transport and use of explosives which are enforceable by law and with BS 5607:1998 and its recommendations.

The contractor shall be responsible for providing all materials such as electric delay detonators, gelatinous explosives, detonation cord, etc. according to the requirements.

The contractor shall obtain a transit license for the transport of explosives from the District through which he intends to travel.
Before construction commences the Contractor shall submit to the Engineer his full proposals for the control of explosives in accordance with this clause. He shall submit details of his proposals for explosive stores on the surface, for means of transportation of explosives in the tunnel and for usage and safekeeping of explosives in the tunnel. He shall supply the Engineer with a list of qualified short firers before the use of explosives commences and shall inform the Engineer of any subsequent changes in the composition of the list.

Firing cables for blasting shall be segregated from all other cables and shall be kept as far away as practicable (on the opposite side of the tunnel or shaft whenever possible) from lighting and power cables and from anything which may carry stray currents or static charges, such as rail track, pipe work or ventilation ducting, whether of metal or other material.

24.4.5. Water

The Contractor shall be responsible for the control of water in undergrounds works and shall keep the Works well drained until the issue of the last Certificate of Completion in respect of underground works.

Measures shall be taken by the Contractor to the satisfaction of the Engineer to prevent pollution of existing watercourses by impurities in water discharges from tunnels and shafts.

Water shall be kept clear of concreting work by grouting or by piping it away from behind the shutter. Water shall not be allowed to run over or through freshly placed concrete.

24.4.6. Ventilation

All underground workings and confined spaces shall be ventilated with fresh air. In any single ended heading there shall be a ventilation system in which fresh air shall forced to the closed end of the heading and exhausts back through the heading unless the written permission of the Engineer has been obtained for any other system. At all times the air in which men are working shall contain not less than 19% of oxygen by volume (dry basis).

The amount of air supplied to each tunnel or shaft bottom shall be sufficient to render the concentrations of noxious fumes harmless (having regard both to the concentration and time of exposure) and to prevent the accumulation of dangers dust or toxic gases and in any case shall not be less than 10 m³/min per man plus 3 m³/min for each horsepower of diesel engine plant working in the heading.

The Contractor shall be responsible for obtaining all information necessary (in the opinion of the Engineer) to determine what concentrations of contaminants are harmless, and his attention is directed to Guidance Note EH 40, ‘Occupational Exposure Limits’ published by the health and safety Executive. Without prejudice to the option of such lower figures as may be stated by the above or other authorities from time to time or ordered by the Engineer, the air breathed by workmen and other authorized persons in underground works shall not contain more than 5 ppm of nitrous fumes (measured as NO₂- Nitrogen dioxide) 50 ppm of carbon monoxide and 5000 ppm of carbon dioxide during the period of 10 minuets after each blast, thereafter reducing to the long terms exposure limit stated in Guidance Note EH 40. Concentrations of fumes in excess of these values will be allowed within a distance of 3 m of the point of discharge of fumes from internal combustion engines provided that no plant operator or other workman stays within range of the excess concentration. The
above ventilation slandered shall apply until the relevant Certificate of Completion is issued.

Petrol driven machinery or equipment and all stationary internal combustion engines shall be used in underground workings. No petrol driven vehicle shall be allowed underground except when an emergency necessitates one, such as need as ambulance.

All internal combustion engines used for any purpose in the underground working shall be specially adapted for the purpose so that the exhaust gases contain the minimum of toxic fumes. They shall be so constructed that:

a) no air enters the engine without first being cleaned,
b) no exhaust gases are expelled from the engine without first being cooled and diluted through an exhaust scrubber, and
c) the engine shall not emit any flames or sparks.

Only low-sulphur diesel fuel shall be used underground unless it is impracticable to obtain supplies.

The Contractor shall ensure that the method of ventilation will be adequate at the extreme length to which any signal heading may be driven. In the event of the breakdown of the ventilation system work shall cease and all men shall be withdrawn from the tunnel if the system is not restored to full operation within 20 minutes of breakdown, or such other period as the Engineer may determine. No relaxation of the requirements for ventilation will be made other than in exceptional circumstances.

No part of any ventilation system shall be dismantled without the authority of the Engineer. In particular the ventilation system shall not be dismantled in any section of tunnel situated between two openings to atmosphere until it has determined that the natural ventilation is satisfactory. Natural ventilation in such a section shall be considered satisfactory if the direction of flow remains constant and is not subject to temporary reversal due to changes in external atmospheric conditions.

24.4.6.1. Method of Ventilation

Rigid or semi-rigid, ducting shall be used for the forced ventilation and all fans and ducting shall be maintained in a leak-proof condition. Semi-rigid ducting shall not be used without the prior approval of the Engineer to the make and type.

Special means shall be taken to minimize the effect of particular sources of fumes, as directed by the Engineer. These means shall include efficient and properly maintained exhaust smoke washers for all diesel engines in undergrounds works, water sprays to act on all muck piles and after blasting, and the provision and operation of suitable equipments for spraying water into the fumes arising from blasting. The means of dealing with blasting fumes shall include either extraction ventilation form immediately before blasting until 20 minutes afterwards, together with an approved compressed air jet to the face to break up the plug of fumes, or such other methods as may be require or agreed by the Engineer.

The ventilation fans shall be erected clear of the tunnel portal or shaft opening so that the air passing back along the tunnel, which may be contaminated by a "plug" of polluted air, is not drawn back into the system.

24.4.6.2. Testing of Air

Not withstanding any requirements specified herein, the method of ventilation and treatment of fumes shall be subject whatever tests may be necessary in the opinion of
the Engineer, and shall be improved as the result of such tests or as the result of more recent information that may become available from time to time. The contractor shall provide, maintain and use an instrument of a pattern approved by the Engineer to measure the velocity of air, and an approved gas detector. Maintenance of the gas detector shall include the supply of all detector tubes.

An electronic gas detector approved by the Engineer shall be maintained at each tunnel face or shafts bottom at all times. It shall be calibrated to provide an alarm when the oxygen content falls below 18% and when the content of methane raises to 20% of the LEL (Lower Explosive Limit) of methane. The total length of the tunnels shall be monitored for methane layers at least once per shift.

24.4.7. Control of Dust

The Contractor shall take necessary precautions to limit the amount of dust formed by underground working. In particular, dust hazardous to health of between 5 and 0.2 microns effective diameter shall be kept to a minimum. Where excavation is by drilling and blasting, no dry drilling will be permitted, arrangement shall be made for hosing down the muck pile before mucking commences. If machine excavation is used, the machine shall incorporate a system of dust suppression which harmful dust reaching the operating crew.

24.5. Excavation

24.5.1. General

The underground excavation shall follow the dimensions and details for different sections as shown in the drawings, except in those areas where special protection is necessary of where, due to local conditions, the Engineer orders modifications, in this case the Engineer shall define the new excavation lines. No protuberances or loose material shall be left within the outlines defined by the design lines. The structural supports for excavations shall be installed in the different sections in accordance with what is specified hereinafter.

Rock tunnel cross-sections shall be measured using inter alias “Photo-profile” apparatus. This system photographs the perimeter of the tunnel cross-section traced out by a source of light; the tunnel clearance line being superimposed on the resulting photographic negative before printing.

The contractor shall allow in his driving program for one stoppage per week of 12 hours duration between 800 and 2000 hours at each heading to enable the engineer to carry out check surveys for alignment, level and cross-section.

The working method for excavation is left to the contractor’s discretion. In case of contractor’s delay, the Engineer reserves the right to stipulate other working methods, if these can be expected to result in a speedier progress of the work. The contractor shall not make any extra claims for such modifications to the working method.

All equipment, materials and structural components which the contractor is to provide for the sole purpose of underground excavation in accordance with the requirements of the contract and which are not permanently incorporated in the works may be new or used materials. All used materials are subject to the approval of the engineer.

All materials and structural components which the contractor is to supply and install and which are permanently incorporated in the works shall be new unless otherwise
specified. All materials must comply with the relevant standards and requirements regarding quality and dimensions and approved by the engineer.

Survey points, benchmarks, boundary stones and the like shall not be removed or obstructed without the Engineer’s written consent. Extra benchmarks to be provided by the contractor shall be indicated by plates, approx. 250 mm×250 mm size, with benchmark inscriptions written in black letters on a light background with clearly legible weatherproof oil-based paint.

A binding working schedule with explanatory report shall be submitted prior to the start of excavation work. The schedule shall show the quantity, type and capacity of the equipment provided, blasting pattern and charges, the working method envisaged for transportation and distribution of excavated materials, the location of stockpiles and main storage areas, as well as the approximate number of site operators, etc. this working schedule and any amendments made thereto during the duration of the contract shall be subject the approval of the engineer and this basis shall be binding for underground excavation if not directed otherwise by the engineer.

Drilling and blasting operations and excavations for rock tunnels shall be carried out according to the New Austrian Tunneling Method (NATM) to meet the following requirements;
- Minimum loosening at the excavation surface and tunnel wall by smooth blasting;
- The least possible vibration to be imparted to all tunnel supports or lining (especially the concrete lining), neighboring tunnels, and the surrounding mass
- Pressure wave of such magnitude as not to have any adverse effects on any formwork.
- The least possible amount of overbreak by pre-splitting method in the roof or along the wall;
- No avoidable rock falls in fault zones.

Damage or alteration at any of the work areas, caused by improper blasting or due to any other operation executed by the contractor, shall be repaired or indemnified by him at his own expense in a manner acceptable to the employer.

The contractor shall take into account the possible variations in the quantities and limits for the different sections when determining his unit prices for excavation. Such variations shall not modify the terms and unit prices and shall give not right for other claims.

24.5.2. Passing Bays

For rock tunnels, the number, sitting, size and shape of any passing bays safety niches and the like required by the contractor for his convenience or to suit his methods of working shall be subject to the prior approval of the Engineer.

Excavation and backfill for temporary passing bays etc. shall be deemed to be included in the rates and the contractor shall completely backfill the excavation with concrete of class A, B or C as per Table 10.1 of Section 10 or as approved by the Engineer.

24.5.3. Temporary Shafts, Adits or Tunnels for Access

If, in order to provide access for construction, the contractor is allowed to construct shafts, adits or tunnels as temporary works, they shall be sealed at the inner end with a concrete plug, when the contractor has completed tunneling. The contractor shall
Section 24: Tunnel Construction

submit for approval details of his proposed method of working to Engineer before
construction commences.

The contractor shall submit his detailed designs for forming the plugs and
backfilling to the Engineer at least 3 months before the plugs are to be formed and shall
later his designs as the Engineer may require.

The entrance to temporary tunnels shall be blocked with rock fill for at least 20
meters to the satisfaction of the Engineer. Temporary shafts shall either be plugged as
specified above, and then backfilled to ground level with rock fill to the satisfaction of
the Engineer, or otherwise made safe as ordered by the Engineer.

24.5.4. Disposal of Excavated Material

All excavated material from the tunnels and surplus material from excavation at the
portals and shafts which is not required elsewhere on the site shall be disposed off in
permanent stable spoil tips situated in locations approved by the Engineer which shall
be trimmed to an approved shape. The contractor may remove the excavated materials
to spoil tips only when there are no possibilities for its further use by him or by the
employer.

All costs of transportation, disposal and compaction shall be included in the unit
prices for underground excavation.

24.5.5. Excavation for Bolted Ring Tunnels in Soft Ground

Soft ground tunnels shall have a primary lining of bolted reinforced concrete rings
and the excavation shall be symmetrical about the axis of the ring and about 50 mm
larger in diameter than the outside of the ring.

The tunnel shall be excavated using a shield. The shield shall be capable of
supporting the ground along its full length and of excavating the tunnel as specified for
bolted rings. Thrust rams, shoes and shoe-packings shall be arranged so that they do not
 cracking, spall or damage the segments of the rings. A tails kin capable of supporting the
ground between the shield and the last ring erected around the full periphery of the
excavation shall be available. The contractor shall submit full details of his proposed
shield, to the Engineer for his approval.

Rams shall be co-axial with the shield and correspond with the centre of each
segment. Segments shall be fully protected by tough rubber or other approved packings
on the ram shoes, these shall bear evenly on the whole of the circumferential joint face
except within 40 mm of the longitudinal cross joint and with a pressure not exceeding
on third of the specified 28 day strength of the concrete. The rams shall move evenly
and continuously throughout their stroke.

Temporary supports outside the limits of the primary lining shall be steel or timber
which has been vacuum/pressure treated with preservation and shall be left in
permanently. Any extra excavation to accommodate temporary support shall be deemed
to be included in the Contractor’s rate for excavation and shall be filled with grout as
specified.

Excavation, except where the ground is supported by a shield, shall not advance
more than 1.0 m beyond the last ring grouted except with the approval of the Engineer.

24.5.6. Excavation through Weak Weathered Rock

Where required the contractor shall excavate tunnels etc. through weak and
weathered rock by methods approved by the Engineer, which shall provide the required
excavation profile but shall avoid cave-ins and slides. He may also use the excavation and transportation equipment that best suits and working conditions and meets with the Engineer’s approval. The excavation shall be coordinated with the installation of supports to provide a permanent support for all the materials surrounding the tunnel. Where rock blocks are encountered, the excavation shall be stated using manual methods or pneumatic tools in order not to disturb neighboring materials. In cause it is impossible to execute the excavation using these methods and it becomes necessary to resorts to explosives blast shall be as specified below. If rock blocks of considerable size are found, it may be necessary to resort to line drilling to diminish any harmful effect form blasting on the remaining material.

Where weak and weathered rock with insufficient strength to retain shape is encountered, the Contractor shall prepare a method statement with sketches and a list of equipment he intends to employ for excavation. The sketches shall show the proposed supports system, drainage measures if any and unavoidable operation like fissure grouting.

The approval of Engineer to the proposals does not relieve the Contractor of his obligations under the Contract.

During excavation all ground water has to be tapped by flexible hoses and conveyed to the tunnel invert.

At the final stage seepage water shall be conveyed by drains of perforated PVC pipes laid with opening joint surrounded by a gravel and sand filter where it is required prior to concreting the bottom of the filter gravel has to be protected with a proper geotextile from clogging. Any expenses arising from difficult excavation conditions due to seepage and ground water flows into the tunnels up to 1 litre/sec per 100m of tunnel, shall be deemed to be paid for under separate items.

24.5.7. Excavation through Generally Prevailing Rock

The Contractor shall execute the excavation through rock by means of smooth blasting according to the NATM. The drilling and blasting pattern has to be approved by the Engineer. He shall use excavation and transportation equipment which meets the requirements stated in these specifications and has been accepted by the Engineer. It is expected that supports and/ or rock bolts will be called for in section where the quality of the rock so indicates. The excavation and support installation operations shall be made in a coordinated way to avoid the action of unbalanced forces on the tunnel supports. Use of explosives shall be made as indicated below in these specifications and the quality, quantity and distribution of explosives for each blasting series shall be only as approved by the Engineer, but such approval shall in no way free the Contractor of any responsibility in this regard.

As the excavation advances the rock encountered shall be classified according to its fractures conditions for determining the length and number of drill holes, the charge of dynamite per hole purpose of reducing the over excavation to a minimum and maintaining the periphery as close as possible to that shown on the Drawings. In difficult rock conditions the contractor should even use detonating cord like cordex or similar. If required, core drilling ahead shall be provided to enable the selection of any appropriate excavation and support method. A systematic and permanent inspection of the surfaces of excavated sections hall be made to determine the quality and conditions of the supports.

The surface shall be cleaned with water and air jets as ordered by the Engineer in order to facilitate their inspection. All shattered pieces of rock shall be removed and
wedges shall be placed to maintain the excavation in a stable position. Where the removal of shattered or loose rock is not sufficient to guarantee that cave-ins will not occur, the vaults and walls shall be supported by means of shotcrete or shall be reinforced by means of rock bolts or steel supports, with or without lagging, as approved and ordered by the Engineer. When it becomes necessary to reinforce a section of a tunnel, etc., this operation shall be finished before continuing with the vaults and walls in such a way as to obtain a safe protection. If the tunnel surfaces which are to be covered, by concrete or shotcrete, show excessive protuberances or depressions that make concrete or shotcrete placing difficult, the Engineer can demand that the surface be trimmed until a surface that allows good lining quality and adherence is obtained. There shall be no separate payment for this trimming operation and its cost shall be included in the unit prices for excavation through rock.

After completion of all underground excavation works through rock and unstable material, the rock surface at the inverts of the tunnels shall be carefully cleaned and prepared as specified hereinafter.

The earth and rock surface shall be free of oil, stagnant or running water, mud, loose rock, residue, and impurities or any other improper material. Rock faults, depressions, and fractures shall be cleaned and all brecciated and decomposed material shall be thoroughly removed to sound rock. If requested by the Engineer cleaning by means of air and water jets shall be made by the contractor to prepare the rock surface for concreting works.

24.5.8. Shaft and Tunnel Excavation Records in Rock

The contractor shall maintain accurate records of all tunneling, shaft sinking and chamber excavation work performed under the contract. The originals of such records shall remain the property of the contractor, but he shall provide three copies to the Engineer for his retention.

The following data for each round of excavation, together with such additional data as the Engineer may request, shall be recorded:

1. Date
2. Chainage to tunnel face or depth to shaft bottom at start of round
3. Drilling pattern including number, location, diameter and length of holes
4. Type and number of drills
5. Type, amount and location of explosive in each hole and the type, location and firing pattern of standard and delay detonators
6. Advance of tunnel face or shafts bottom and chainage or depth at end of round
7. Solid volume excavated
8. Geological and geometrical details of tunnel or shaft cross-section after blasting. The geological details shall include:
   a) Lithology and geostructures in the opening
   b) RMR value calculated for the rockmass
   c) Water inflows
   d) Engineering geological mapping of the face
   e) Rock mechanics tests as required
9. Number, location and type of structural steel supports installed
10. Area of lagging installed
11. Number, length, location and type of rock bolts installed
12. Thickness and area of sprayed concrete used
13. Number and classification of persons engaged in tunneling or shafts sinking
14. Results of gas tests
15. Times and time elapsed for:
   a) Moving in and setting up
   b) Drilling
   c) Loading and firing
   d) Mucking out
   e) Idle time
   f) Laying and extending tracks and services
   g) Installation of temporary support

Completed records shall be handed to the engineer within 24 hours of the round being fired.

24.5.9. Shaft and Tunnel Excavation Records in Soft Ground

The contractor shall maintain accurate records of all soft ground tunneling and shafts sinking work performed under the contract. The originals of such records shall remain the property of the Contractor, but he shall provide three (3) copies to the Engineer for his retention.

The following data for each shifts, together with such additional data as the Engineer may request, shall be recorded.

1. Date
2. Chainage tunnel face or depth to shaft bottom at start of shift
3. Advance of tunnel or shaft bottom and chainage or depth at the end of shift
4. No. of rings built during shift
5. No. of rings grouted during shift
6. Line of rings
7. Level of rings
8. Plumb of rings
9. Lead of rings
10. Face geology
11. Results of gas tests
12. list of manpower & equipment etc
13. Times and time elapsed for:

Completed records shall be handed to the Engineer within 24 hours after the shift.

24.6. Supports

24.6.1. Bolted Concrete Rings

The type of bolted lining shall be proposed by the contractor and shall be subject to the approval of the Engineer.

Bolted concrete rings shall be designed by the contractor or by a specialist in precast concrete tunnel lining manufacturer or similar approved. The contractor shall cast the segments on site using segment moulds provided by a specialist manufacturer. The bolted rings shall be of precast reinforced concrete grade 40 with 10 mm aggregate complete with bolts, nuts, washers, grommets gaskets, bituminous packings and grout plugs. Concrete used for bolted rings shall comply with the specifications in Section 10, “Concrete Structures”.
The contractor shall set up the precasting facility with the assistance of the lining manufacturer and a representative of the lining manufacturer shall be resident on site throughout the production of the tunnel lining rings.

The contractor shall submit for the Engineer’s approval a detailed method statement for precasting the bolted tunnel lining. This method statement shall include:
- Lining general arrangement and reinforcement details;
- Name and experience of lining manufacturer;
- Details of precasting facility.

Precasting of the tunnel lining shall not commence until this statement has been approved by the Engineer.

24.6.1.1. Erection of Bolted Ring

Bitumen packings shall be sweated on to the segments in accordance with the manufactures recommendations.

The square, plumb or plan of any ring shall not deviate more than 12 mm. where these limits or those specified are exceeded, the Contractor shall dismantle, replace as necessary and re-erect the rings correctly at his own expenses.

Packing between the segments may be used to assist in the erection of bolted rings in the correct adjustment. The maximum total thickness of packing in a joint shall be as specified.

Tunnel segments shall be erected and assembled in situ ring by ring. The segment joint faces shall be clean on erection. The lining shall be built as soon as possible after the ground has been cut. Any loose material or other obstruction shall be removed from the excavated surface immediately before segments are installed.

For segment joints to be bolted to tunnel linings, the longitudinal joint bolts shall be tightened before the final tightening of the circumferential joints bolts connecting the ring to the adjacent ring. Each ring shall be tightly bolted through all bolts holes and each bolts shall have a mild steel washer and grommet as specified under both the head and the nut.

Any segment or other item material used in the erection of bolted rings, which in the opinion of the Engineer is damaged or has deteriorated shall be removed from the site and replaced by the Contractor at his own expense.

24.6.2. Steel Supports

The work covered by this Article includes manufacturing and installation of all steel supports, as well as furnishing of lagging, wedges, tie-rods and other accessories required to excavate tunnels and shafts with supports in a safe and efficient way. Furnishing of equipment, labor, and elements needed to place the supports, and any other operations regarding the installation of supports for the construction of tunnels and shafts are also included in this Article.

The zoning of tunnels and shafts shown on the contract documents, indicating the geological characteristics is based on visual inspection and limited investigation. Such zoning has been done in order to facilitate the elaboration of tenders, but the actual needs appearing during construction will not be an excuse to modify the unit prices stipulated in the bill of quantities to change the terms of the contract or to diminish the contractor’s responsibility.
The contractor shall propose for approval of the Engineer the type, size, locations, and spacing of members and method of placing.

The Engineer may approve the contractor’s proposal or he may order modification of the type and/or method proposed or the adoption of a different type and/or method. The contractor shall be solely responsible for the adequacy and successful functioning of the supports.

The absence of the order for the installation of supports, or of the approval of the proposed supports by the Engineer shall not relieve the contractor of this responsibility for tunnel excavation. In any emergency, the contractor shall promptly bring the installation of supports and submit his scheme thereafter as soon as possible for subsequent approval.

Sufficient support material shall always be on hand at each portal or shaft from which tunnel driving is in progress in order to carry out the work without delay. In case of tunnel failure due to shortage or lack of equipment and / or material the contractor will be fully responsible.

Nothing specified in this Article shall prevent the contractor, at his own expense, from installing such amounts of supports or timbering or steel liner plates, as he may consider necessary for the safety of tunnels, nor shall anything herein be construed to relieve the contractor from his sole responsibility for the safety of the tunnel or other structure or from liability for injuries to, or deaths of, persons or damage of property.

24.6.2.1. Materials for Steel Supports

The Contractor shall furnish all steel supports consisting of structural steel ribs of wide flange shape about 200 mm maximum depth or approved equal, foot beams, lagging, steel sheets Type BERNALD or similar, wire mesh null oilier approved structural steel members, complete with bolls, nuts, wedges, lies rods, and other accessories required for assembling the permanent structural steel supports and supporting them in place.

If structural steel supports are required for irregular tunnel section, such as may occur at tunnel portal transitions and tunnel plugs, such supports shall also be in accordance with designs approved by the Engineer. The amount of structural steel supports that will be required is uncertain, and the Contractor is not entitled to an additional allowance above the unit prices in the Bill of Quantities by reason of a larger or smaller amount.

All structural steel shall be new and unrusted stock and shall conform to the requirements of the relevant technical standards and "Test and Properties".

Concrete for foot beams shall meet applicable requirements of concrete items, and shall be of sufficient strength to carry the loads imposed thereon.

Timber for temporary timbering shall be furnished by the Contractor and all timber shall be well-seasoned sound timber. The Contractor shall submit the type and dimensions of timber for the approval of the Engineer.

The Contractor shall obtain the Engineer's approval for the type of lagging he intends using at least four weeks prior to commencing excavation.

24.6.2.2. Installation of Steel Supports and Lagging

Steel supports shall be placed in an approved manner to the lines, grades, and dimensions approved by the Engineer. Actual spacing of the structural steel supports shall be determined by local conditions revealed by the tunnel excavation but the
Section 24: Tunnel Construction

Supports

Spacing in general shall not exceed 1.5 nor be less than 0.5 m. For the uniform distribution of pressure, collar braces between the structural steel support sets shall be held in place by tie rods to complete the support system.

Placement of steel supports shall be done as soon as possible after tunneling of each face is finished and in such a way that the natural strength of the rock is optimally used.

The maximum unsupported advance in each front will be determined by the Contractor at work site, according to the soil or rock conditions, so that cave-ins in ceiling, walls or front of the tunnels do not occur. Wherever excessively soft, loose or disturbed rock is found, it may be necessary to install supports in advance of excavation. The Contractor shall provide provisional support for the face and excavate in benches, placing simultaneously the required support if the conditions require it. Wherever lateral pressure is great or where there is a danger of ribs moving inwards, steel invert struts shall be installed in order to support such load and avoid the lateral displacement of the main supports.

Where arched steel rib supports are used, care shall be taken to ensure that the arched rib is subjected to uniform load throughout its circumference; i.e. those parts of the arch not resting against the rock shall be supported on the rock by means of short props or wedges. An adequate longitudinal bracing system shall be provided as a safeguard against collapse of the supports.

Installation of supports shall be done in such a way as to keep grades and alignments of tunnels and shafts in accordance with the Drawings. In tunnels, steel ribs shall be pin jointed at the top of the arch and if joints are required at the mid-height level they shall be full-strength bolted joints between flush fitting plates welded to adjacent rib sections. The ribs shall be set on steel bases on the floor of the tunnel or on foundation concrete; blocks. The base shall be spiked to the tunnel floor and set in concrete. If the foundation is poor, the ribs shall be supported on each side of the tunnel with a pin jointed connection to continuous longitudinal steel ground beams. The ground beams shall be firmly located and supported by means of dowels, footings and wedges and may be surrounded in concrete provided the concrete does not project within 150 mm of the finished concrete surface. The ribs shall be blocked off the rock with treated or hardwood timber blocks and wedges at not more than 1 m centers.

Where spreaders and such appurtenances are required to remain in place, as approved or as directed by the Engineer, such appurtenances shall be structural steel or equivalent material.

Rock loads shall be transmitted to the supports by means of shotcrete only as indicated on the Drawings. Wedges shall be placed carefully, well blocked at the bottom. Whenever the conditions allow it, wood wedges shall be removed before the placement of concrete or shotcrete lining.

Steel lagging shall be suitably fastened to the supports with bolts, clips or by other approved methods. The Contractor shall remove such lagging as may be ordered by the Engineer shortly prior to placement of concrete lining or shotcrete. Lagging removed shall become the property of the Contractor and if suitable may be re-used in the Works: Lagging welded to the steel supports shall be backfilled with Class A, B or C concrete given in Table 10.1 in Section 10 or as approved by the Engineer.

Concrete or structural steel foot beams shall be installed to provide a firm base and support for the structural steel ribs until the concrete lining is completed.

In general, the permanent steel supports shall be firmly and securely placed and kept secure in position so as not to be disturbed by the tunnel lining or by any of the
Supports  
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Contractor's operations. Improper supports and/or steel supports damaged by the Contractor's operations shall be repaired or replaced, at his expense, immediately.

The Contractor may suggest to the Engineer changes in the design of the support, whenever such charges permit a saving of materials, ease of installation or any other advantage. However, the Contractor shall not make changes without the written permission of the Engineer.

Where circular ribs are used in a shaft, the ribs shall be adequately supported during and after erection on steel bars dowelled into the rock, and shall be blocked off the rock with timber blocks and wedges at not more than 1 m centers. The ribs shall be set to a tolerance of plus or minus 50 mm in all directions relative to the shaft centre-line. The minimum clearance between the ribs and the face of concrete lining shall be 150 mm except where otherwise specified.

Great care shall be taken to set up ribs accurately as allowance must be made for any deflection or movement of the ribs, and no additional tolerance will be permitted at the time of forming the concrete lining. In particular ribs should be set no lower than that level which allows the nominal clearance to the highest part of the inner face of the concrete lining.

Thin struts, ties or spacer bars between the ribs will be permitted to remain between the ribs will be permitted to remain within the clearance line, but all lagging, blocking, wedging and any materials used as support the ground shall be no more than 25 mm inside the clearance line.

The Contractor shall establish to the satisfaction of the Engineer a suitable system for measuring the weight of steel used in approved ribs and ground beams and shall submit his proposals to the Engineer at least four weeks before shaft excavation and tunnel driving starts.

Immediately after erection of steel ribs, and before any further excavation stakes shall place, full and adequate support to the sides of shafts and to the sides and roof of the tunnel shall be provided by one of the following means:

1. By blocking, wedging and cribbing with timber between the ribs and the ground surface. The timber shall be hardwood or appropriately treated, durable softwood. Gaps equivalent to at least 50% of the area supported by the timber lagging and uniformly distributed around the rib shall be left open to facilitate placing of concrete against or timber blocks or braces held: tight with timber wedges. No timber shall be left in place between, the webs or inner flanges of steel arch, ribs.

2. With continuous steel or timber, lagging outside the ribs and the space between the lagging and the ground filled to the approval of the Engineer with grouted rock-fill, as tightly compacted as possible, or with concrete that shall not be weaker than Class C in [Table 10.1](#).

### 24.6.3. Rock Bolting

#### 24.6.3.1. General

The contractor shall provide and install rock bolts to exposed excavated slopes and in underground excavations where directed or approved by the Engineer. Rock bolts shall be installed to the lengths and nominal diameters directed or approved by the Engineer and shall be provided with 150 mm² bearing plates.
Rock bolts or anchors shall be used in the zones indicated on the Drawings, or in those places where the Engineer orders it according to the rock conditions. The rock bolts or anchors shall be installed such that:

- Placed in position and subjected to a certain amount of tension immediately after driving, they press possibly loosening layers together so that the original rock stress is maintained;
- By fixing the loosening layers of the natural vault preserve a state of equilibrium which will prevent deformation and cave-in
- Rock bolt support results in uniform tensioning of all anchors rather than the use of the actual amount of tensioning load applied.

In tunnel headings, the installation of rock bolts shall not lag more then 10 m behind the driving face. Where directed by the Engineer, rock bolting shall be carried out at the face immediately following the excavation of the shaft to its full section, and in no case shall lag more than 5 m behind the excavation to full section.

Where grouted rock bolts are provided for the purpose of producing a permanent arching effect in unstable rock or for securing loose rock parts in otherwise stable rock, the rock bolts shall be placed by mechanical means only. Its capacity shall, at the Engineer’s request, be proven by means of a torque wrench which shall be regularly checked for safe and accurate functioning.

Details of rock bolts and accessories and methods of installation, including the equipment necessary to drill the hole, effectively anchor the bolt in the hole, tighten or stress the bolt to the required tension and grout the rock bolt during or after installation shall be subject to the approval of the Engineer. Where polyester resin is used, the manufacturer’s recommendations shall be followed.

In order to form a basis of submission of his proposal, the Contractor shall install grouted trial bolts that shall be tested by standard pull-out tests. These tests shall be carried out prior to the underground excavation works and shall not be paid for separately.

The Engineer may approve the Contractor’s proposal of the type and method of installation. The Contractor shall be solely responsible for the adequacy and successful functioning of bolts, anchors and other supports, as well as any damages thereof. The approval of the Engineer shall not relieve the Contractor of his responsibility for the safety of the workers or for providing adequate support for the tunnel excavation or open-cut excavation, and in any emergency, the Contractor shall promptly begin the installation of supports and submit his scheme as soon thereafter as possible.

Bolts whose anchors fail to sustain the required tension shall be duplicated and such duplication shall not be measured for payments.

24.6.3.2. Materials

1. Steel for Rock Bolts and Dowels

Mild steel rock-bolts shall be manufactured form as per specifications or as directed by the Engineer. A minimum of 0.5% of all bolts shall be tested including bolt assemblies after threading and the Contractor shall submit the Certificates to the Engineer for each type of bolt to be used in the Works.

2. Types of Rock Bolts and Dowels

Rock bolts may be of the following types:
a) Mild steel bolts with mechanical expansion anchors that either remain ungrouted or have a separate air release pipe for grouting with mortar or resin.
b) Mild steel or high tensile steel bolts with quick setting polyester or epoxy resin anchorage.
c) Mild steel or high tensile steel bolts with quick setting polyester or epoxy resin anchorage with the remainder of the bolt to the rock face to be embedded in slow setting resin.

Dowels may be of mild steel or high tensile steel bars which are full column grouted with mortar or resin.

All rock bolts and dowels shall be provided complete with threaded ends, nuts, washers and face plates. Spherical washers shall be used between nut and face plate where bolts or dowels are installed at an angle to the rock face.

3. Cement Grouts for Rock Bolts and Dowels
   Cement grout shall consist of Ordinary Portland cement and water with a water/cement ratio not exceeding 0.45 consistent with high workability with the addition of an approved “expanding” additive.

   Water for mixing shall comply with the requirements of Article 10.4.4, “Water” in these specifications.

   Admixtures shall only be used if tests have shown that their use improves the properties of the grout, e.g. by increasing workability, reducing bleed, or expanding the grout slightly. Admixtures shall be free from any product liable to damage the steel or the grout itself.

   Expanding agents containing aluminium to give grout expansion of up to 5% may be used in accordance with the manufacturer’s instructions.

   Cement grout shall have a minimum uniaxial compressive strength of 20 MPa at 28 days.

4. Resin Grouts for Rock Bolts and Dowels
   Epoxy or polyester resins shall be shown to be proved by tests and/or practical experience to have the following properties:
   1. Adequate strength to transfer the applied stress permanently.
   2. Suitably inert in the surrounding ground conditions.
   3. Capable of proving a barrier against corrosion of the steel bar.
   4. Adequate bond strength with the bar or adhesion in the case of smooth surfaces.
   5. Adequate ductility to ensure compatibility with load/extension characteristics of the steel up to 75% of the ultimate tensile strength.
   7. Sufficiently fluid, at installation temperature, prior to setting, to fill the void completely.
   8. Minimal creep under service load conditions.

   Post- gelation shrinkage shall be minimized and in no circumstances shall be more than 5%.

   Resin grouts shall have minimum ultimate compressive and tensile strengths not less than 75 MPa and 15 MPa respectively. The extension at failure shall not exceed 2%.
Resin grouts and grout capsules shall be obtained form a specialist manufacturer approved by the Engineer.

24.6.3.3. Installation

For all types of rock bolt, the holes into which they are to be inserted shall be drilled to the lengths and diameters needed to suit the bolt lengths and diameters and the requirements of the mechanical anchors or the recommendations of the supplier of polyester resin, whichever is appropriate. Before inserting rock bolts or accessories, the holes shall be thoroughly cleared of all dust and debris by the use of compressed air.

After a rock bolt has been anchored in a drill hole it shall be tensioned by means of a jack or torque wrench to the value specified or shown on the Drawings or determined by the Engineer. The tension in each rock bolt shall not normally exceed 50% of the ultimate strength of the bar.

Subsequent to initial installation, the Contractor shall provide access to permit periodic inspection of all rock bolts by the Engineer and shall torque test bolts and retighten nuts to the approved torque value, as may be necessary and directed by the Engineer. All bolts within 10 m of a blasting operation shall be torque tested within 4 hours after blasting and the nuts retightened to the approved torque value. In the case of cement grouted rock bolts a final check on torque value shall be made immediately prior to grouting.

To avoid exfoliation of rock layers after the excavation, the anchors shall be placed as soon as possible as mentioned above and as directed by the Engineer. The loosening area (in cross-section) around the excavation line can, by way of very general approximation, be assumed as an ellipse whose top and bottom extends above the crown and below the invert, respectively of the excavated cross-section by nine-sixteenths (9/16) of the width of the excavated section and whose sides extend three sixteenths (3/16) of the width of the excavated section beyond the side walls at mid-height of the excavated section.

The drill-holes shall be of circular cross-section and shall be drilled dry for expanding anchors. Suitable exhausters to collect rock dust shall be used in drilling and the drill-holes diameters shall be adapted to the anchor grip head and the bar diameter.

The drill-holes for grouted rock bolts shall be wet-drilled to improve bonding of the concrete.

The anchor surface plates shall bear upon the rock over the largest possible area. A flat, straight plate is suitable only for cock faces that are perpendicular to the direction of the anchor. If the surface plates lie obliquely to the direction of the anchor, they will exert a detrimental one-sided edge pressure on the hexagon nut, which shall be avoided.

For bearing surfaces not perpendicular to the anchor direction, spherically dished anchor plates with a slotted hole shall be used since they are more suitable for adjustment over unsmoothed areas. The hexagon nut shall invariably bear upon the surface plate on two sides of the slot.

The Contractor shall always bear in mind that the success of rock bolt and anchor support very much depends on careful supervision of the tensioning load.

Since the rock anchors and rock bolts must constantly keep its tensioning load, it should be checked regularly.

Immediately before placing the nut, hardened steel washer with anti-corrosive liquid shall be put on the bolt. Before the bolts are inserted, every one of their threads shall be completely cleaned and lubricate with anti-corrosive product to be furnished by
the Contractor. Anti-friction produced shall be applied to the nut surface in contact with the washer. Such product shall also be furnished by the Contractor.

The heads of the bolts are to be covered completely by concrete or shotcrete, which will protect the steel from corrosion. Prior to this, the surfaces of these elements shall be free from oil, grease and any other foreign material, for which, if necessary, they shall be cleaned with solvent and steel-wire brush, or by means of other approved methods.

The protruding ends of the bolts embedded in concrete or shotcrete, shall be carefully left free of grease, oil, etc., The Contractor shall clean them with a solvent and steel-wire brush, if necessary.

If the diameter of the drill-holes is too narrow, it is difficult to insert the anchors, whilst if the holes are too wide, the anchors will tend to slop. Therefore, drilling of the drill-holes shall follow the correlation of anchor types and the respective drill-hole diameters as given below in Table 24.1 or according to recommendation given by the manufacturer.

Table 24.1: Anchors diameters and its corresponding drill-hole diameters

<table>
<thead>
<tr>
<th>Diameter of Anchor (mm)</th>
<th>Drill-hole Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td>20</td>
<td>36</td>
</tr>
<tr>
<td>24</td>
<td>40</td>
</tr>
<tr>
<td>26</td>
<td>45</td>
</tr>
<tr>
<td>28</td>
<td>50</td>
</tr>
</tbody>
</table>

In case of aggressive ground water, the diameter of the drill-hole shall be enlarged to 3-4 times of the bolt diameter. Prior to placing the rock bolt, the drill hole shall be completely filled with grout material to guarantee a reliable corrosion protection.

Anchor bars shall be cleaned thoroughly before being placed. The holes shall be drilled wet, cleaned thoroughly by means of water and air under pressure and shall be completely and compactly filled with grout mixed in the proportions and to the consistency prescribed by the Engineer.

24.6.3.4. Ungrounded Installation

Where an ungrounded rock bolt with mechanical anchor is required, the bolt shall be tensioned as described in Article 24.5.6. The tension shall thereafter not be released for any reason, except with the approval of the Engineer.

Where an ungrounded rock bolt with polyester resin anchorage is required, sufficient cartridges of quick setting resin shall be inserted in the drill hole such that when the bolt is fully inserted, the end remote from the rock face shall be embedded in resin for a length of at least 300 mm. the bolt shall be rotated mechanically to effect full penetration into the drill-hole and thorough mixing of the resin components. The rock bolt shall be tensioned when the resin has reached the required strength, and the bolt tension shall thereafter not be released except with the approval of the Engineer.

When rock bolt are used as temporary support in areas where a permanent lining is to be constructed at a later stage, ungrounded rock bolts shall be used.
24.6.3.5. Resin Grouted Bolts

Where grouting of a rock bolt with polyester resin is required the quantities of quick and slow setting resin cartridges to be inserted into the drill-hole shall be such that, when the rock bolt is fully inserted, the end remote from the rock face shall be embedded for a length of 300 mm in quick setting resin, and the remainder of the bolt to the rock face in slow setting resin.

After insertion in the drill-hole, the rock bolt shall be rotated by mechanical means and forced into the drill-hole so as to reach full penetration and thoroughly mix the resin components.

The rock bolt shall be tensioned as described in Article 24.6.2.2 when the quick setting resin has attained sufficient strength, and before the slow setting resin has hardened.

Prior to the grouting of the drill-holes, the grouting method applied, the corresponding equipment as well as the grout mix shall be approved by the Engineer.

24.6.3.6. Cement Grouted Rock Bolts

Where grouting of rock bolts with Portland cement grout is required, the Contractor shall ensure that all preparations necessary for the injection of grout and the release of air to and from the drill-hole have been made before the rock bolt is tensioned. Rock bolts shall not be grouted with cement within 10 m from a point where rock blasting, other than trimming, will take place within 90 days after grouting the bolt. Immediately before grouting, the rock bolt shall be tested to the approved torque value and the nut re-tightened as necessary.

Grout shall be forced into the drill-holes to fill the space between the rock and the rock bolt up to and including the anchorage of the bolt. The grouting pressure shall not exceed that necessary to comply with the above requirement. If during the grouting of any bolt, grout is found to flow from points in the rock surface adjacent to the bolt; such leaks shall be plugged or caulked.

The grout specified in Article 24.6.3.2.3 shall be mixed for a minimum time of three minutes, by means of high speed mechanical mixer, and passed through 1 mm aperture wire cloth. The grout shall be used as soon as possible after thoroughly mixing all ingredients but in any event within one hour after the addition of aluminum powder to the cement and water.

Grout mixtures, use of admixtures, methods of mixing, grouting pressures and the equipment used for grouting shall be subject to the approval of the Engineer.

24.6.3.7. Steel Dowels

Where steel dowels are used, they shall be installed in drill holes of the size approved by the Engineer and grouted in accordance with the provisions for rock bolts.

24.6.3.8. Spacing Rock Bolts

If not specified in the contract documents or not shown in the working drawings or not directed by the Engineer, as a rule, the anchors and rock bolts shall be equally spaced across the rock surface to be supported, with the number of anchors used depending upon the nominal capacity of the anchors and the rock load to be supported. Where local tension relief movements occur, the number of anchors shall be increased for the areas involved.
24.6.3.9. Testing of Rock Bolts

The Contractor shall furnish certified copies of reports to the Engineer of all tests required to show the compliance with the applicable standards, the specification and recommended instructions by the manufacturer.

Before any type of bolt or anchor is used, its suitability for the intended purpose shall be proved by standard pull-out-tests.

1. Standard Pull-Out Tests

In order to prove the proper functioning of the grouted rock bolts, standard pull-out tests shall be carried out on such rock bolts. Time and location of testing shall be determined by the Engineer. At least 10 pull-out tests shall be carried out prior to placing the permanent rock bolts in the tunnels. Length and load of rock bolts to be tested shall be chosen by the Engineer.

The tests shall be carried out in load steps (increase of load) of 25 per cent of the nominal load till failure of the grouted rock bolt occurs. A new load step shall be added when strain tends to rest. For each tested rock bolt a test report shall be prepared by the Contractor showing at least the stress-strain behavior of the grouted bolt. No separate payment shall be made for standard pull-out-tests.

2. Tensile Tests

Installed rock bolts as permanent support shall be tested by tensile tests. At least one out of twenty five installed rock bolts shall be tested in the presence of the Engineer. The time of testing as well as the rock bolts to be tested shall be selected by the Engineer. The tests shall be carried out in load increases of 20, 40, 80, 100 and 120% of the nominal load. Depending upon the stress-stage at 120% of the nominal load shall last for at least 10 minutes. If no load decrease appears within this time, it will be assumed that the bond stress between the rock and the bolt or anchor is sufficient. The test load may then be decreased to the nominal load or according to the Engineer’s instructions.

The measured values shall be plotted as stress-strain diagrams and shall be added to the test report. All expenses for the tensile tests and corresponding reports shall be included in the unit price of the different types of rock bolts.

24.6.4. Shotcrete Support

The following requirements in addition to these in Section 23, “Pneumatically Applied Mortar (Shotcrete)” in these specifications shall be applied.

- Cement shall be sulphate resisting where directed by the Engineer. Its material uniformity shall be guaranteed.
- Where chemically aggressive ground water occurs, a special cement or Portland cement with a admixture of additives shall be used. The minimum cement content shall in this case be 400 kg/m³.
- Only dry mix equipment will be approved.
- In all areas where excavation is proceeding, the contractor shall ensure that sufficient equipment is available to apply shotcrete at any face, as specified herein.
- In cases where the surfaces are exposed to ground water a chemical analysis of the water in respect to sulphate content and carbonic acid shall be made before the Engineer will approve the placement of the shotcrete. For surfaces requiring immediate placement of shotcrete the Contractor shall advise the Engineer...
accordingly and shall be prepared to execute all necessary operations without any delay upon the Engineer’s approval. The Engineer shall be requested to examine rock faces following blasting and scaling operations and will direct the Contractor, if required, to proceed with the immediate shotcreting of surfaces so that placement of shotcrete shall be performed not later than four (4) hours after blasting and before drilling of the next round. Where very poor rock conditions are anticipated the Engineer may require that shotcrete equipment be available before blasting so that shotcrete can be applied with the minimum of delay.

- If reinforcement is to be embedded, the nozzle shall be held at a flatter angle and closer to the surface, so that voids cannot form under the steel bars.
- The water pressure shall be greater than the air pressure to ensure complete wetting of the material at the nozzle and to give the nozzle man a quick, positive control. The minimum pressure of water shall be 3.5 bars, and the pressure water shall be free from oil and shall not be liable to pressure fluctuations.
- When coatings 25 mm or more in thickness are to be applied to vertical or overhanging surfaces, the shotcrete shall be applied in two or more layers of not more than 19 mm in thickness to prevent sloughing of the freshly placed material.
- For level of slightly sloping surfaces, the thickness of a single layer may vary from 25 mm to a maximum of 100 mm. When more than one layer is applied, a delay of 30 to 60 minutes between applications is usually adequate to prevent sloughing.
- Construction joints or stop joints shall be provided as approved or required by the Engineer and shall be sloped at 45 degrees to the adjacent shotcrete surface in a clean, regular edge. Before placing the adjoining work, the sloped portion and adjacent shotcrete shall be prepared as specified herein.
- Before a succeeding layer of shotcrete is placed, the preceding layer shall be checked for drumminess, to the satisfaction of the Engineer. The Contractor shall repair all drummy, sandy, cracked or spilled areas and any other area where, in the opinion of the Engineer, the shotcrete is faulty, by removing the shortcrete to a sound area of rock or shotcrete, carrying out surface preparation as specified herein and reshooting that area to the satisfaction of the Engineer.
- The Contractor may use shotcrete as temporary support. Such concrete shall lie outside the clearance line. It shall be applied soon enough after blasting to retain the arch action of the rock. The Contractor shall therefore be prepared to spray within an hour of blasting, and if necessary before mucking out.
- Before applying temporary support which will hinder subsequent inspection of the rock surface, the Contractor shall, after blasting, advise the Engineer verbally and make a report on a form to be approved by the Engineer. The form shall include descriptions of the conditions of rock, the thickness of shotcrete to be applied as temporary support in that section of the tunnel, what reinforcement (if any) is required or whether any other temporary support is to be installed. The report shall be submitted to the Engineer if possible before the rock is covered over and in any case within 24 hours of blasting.
- The Contractor shall afford the Engineer reasonable facilities for inspecting the rock before concrete spraying, and shall draw his attention to any rock conditions which he considers of special importance.
- Where shotcrete is applied at once the Contractor shall remove all insecure rock which may cause injury or damage through falling. Elsewhere the Contractor shall
 remove such pieces as would otherwise endanger persons working below then before the shotcrete has hardened.
- For approximately every 1000 m² of tunnel lining, one test consisting of three panels shall be performed.
  
  If the test results are unsatisfactory, the test shall be repeated at the Contractor’s expense on a sample taken from the in-place shotcrete. At the request of the Engineer and without any extra payment, test specimens shall be drilled or otherwise removed from the finished tunnel or other lining and brought to the site laboratory.

24.7. Grouting Works

24.7.1. General

Five separate grouting procedures are required, each serving separate purposes, as follows:

1. Cavity grouting comprises the filling with thick gout at low pressure of the whole of the void outside shafts or tunnel lined with bolted precast concrete segments. Other locations where cavity grouting shall be carried out are: the space around ‘flanges’ of steel tunnel lining taken through the precast concrete lining, and the void between steel tunnel lining and the precast concrete lining.

2. Secondary grouting comprises the injection under pressure of relatively thin grout mixes behind bolts precast concrete lining which have already been cavity grouted. Secondary grouting is intended to stop leakage into the shaft or tunnel.

3. Contact grouting to fill voids in tunnel lining and between the lining and surrounding rock.

4. Fissure grouting shall be use in areas where the rock proves to be highly jointed the infiltration of water may become too high to be tapped by hoses or pipes, or to grout between lining and rock where no large cavity exists. In such a case the excavation works might be hampered by the strong infiltration of ground water. The Contractor shall provide pumps, mixers, recording devices, manometers, hoses, couplings, packers etc. to shall the water bearing joint by means of cement grout.

5. The Contractor shall supply all necessary equipment including high-pressure pumps, hoses and fitting, and all consumable materials. The chemical, i.e. hardener and filler must be non-toxic to groundwater all shall be tested prior to their approval by the Engineer.

24.7.2. Equipment for Cavity Grouting

The Contractor shall provide all necessary equipment for cavity grouting of the bolted precast concrete tunnel lining. This equipment shall normally be located permanently at the tunnel face but may be transported into and out of the tunnel as required. Cavity grouting equipment shall include (but not necessary be limited to) the following:

- one high speed colloidal mixer
- one agitator
- Hoses, values and grout guns compatible with the grout holes in the precast segments.

The Contractor shall ensure that standby cavity grouting equipment is available on site at all times.
Subject to the approval of the Engineer cement grout for cavity, grouting may be prepared at the tunnel face or on the surface. In case of the latter, the grout shall contain a suitable retarding agent to ensure that the grout does not start to set prior to injection. Grout mixed on the surface shall be transported to the tunnel face by means of a purpose built rail mounted agitator. Immediately prior to injection, the Contactor may add a suitable accelerating agent to the grout to counteract the retarded and speed up the initial set. The use of such additives shall be subject to the approval of the Engineer.

24.7.3. Equipment for Fissure Grouting

The contractor shall arrange his equipment in such a way that all agitators’ mixers, pumps and recording devices are mounted on a stable frame which can easily be shifted from one site to the other.

The grouting unit shall contain the following main equipment
- two (2) agitators;
- one (1) high speed colloidal mixer;
- one (1) agitator with a recording device of the grouted mix;
- two (2) grout pumps, e.g. double piston type, with a recording device of the applied pressure.

Similar equipment shall be used for secondary grouting.

The Contractor shall provide sufficient packers, either of mechanical or pneumatic type, equipped with a tap or slide and pressure hoses couplings and branches to grout several holes at the same time. The size of the packer has to match the drillhole diameter which shall not be less than 38 mm.

The drilling of the grout holes shall be performed by drill hammer or drilling machine which shall be supplied by the Contractor.

24.7.4. Materials for Cement Grout

24.7.4.1. Cement

The cement used for grouting should be of Portland type or sulphate resisting where directed by the Engineer with the following specification.

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blain value</td>
<td>over 3000 cm²/g</td>
</tr>
<tr>
<td>Grain size 90%</td>
<td>less than 0.01 mm</td>
</tr>
</tbody>
</table>

The Contractor shall submit to the Engineer for his approval the manufacturers or supplier’s certificate of compliance the required standards/specification. Reference is made to sub-section of concrete section regarding quality assurance, testing facilities as well as delivery and storage.

24.7.4.2. Bentonite

The bentonite will be added to stabilize the cement grout and to improve its characteristics. For this purpose water and bentonite will be mixed in an agitator at least 24 hours prior to application. Only in the pre-swollen condition it will be transferred to the high speed colloidal mixer. The content of the bentonite will range between 2 and 4 percents of weight of the cement.

24.7.4.3. Water

The water must meet the requirements as specified in concrete section.
The water cement ratio will range between 1.0 and 0.5 and will be adapted to the situation at the site by the Engineer.

24.7.4.4. Filler
If the grout take during fissure grouting exceeds 200 kg per meter, filler has to be added. The filler may, among other, consist of:
- Fly ash
- Rock flour

The filler must be non-toxic and has to comply with the grain size of the cement. The Contractor shall submit to the Engineer for his approval the manufacturer’s or supplier certificate.

24.7.5. Cavity Grouting of Precast Concrete Tunnel Linings
The whole of the void outside the ring shall be filled with thick cement grout as soon as possible after the ring is erected. The void shall be vented to ensure that air is not trapped. The grout shall have as low a water/cement ratio as practicable. Grout shall be mixed and placed using equipment and methods of working to the approval of the Engineer.

Caulking grooves shall be cleaned and any projecting packing cut out. Where ordered by the Engineer, caulking grooves shall be filled with a caulking compound in accordance with the manufacture’s instructions.

Grouting shall commence at the lowest holes for the void section and shall continue until the void is filled. Grout holes shall be filled with mortar plugs as specified but timber plugs may be used temporarily when holes are to be opened for venting later grout inputs and are not provided with steel plugs.

At the end of each session of grouting, excess grout in the mixing and placing plant and any grout spilt on the lining shall be removed.

Should any leaks occur, the Contractor shall carry out a programme of secondary grouting through holes drilled through the segments, clear of the segment flanges, to the approval of the Engineer until all leaks are stopped. The pressure used shall not exceed the ground pressure at the depth involved unless the Engineer has approved the use of higher pressures.

Records shall be kept of the amount of grout injected in each section of shaft or tunnel and copy supplied to the Engineer daily.

To help prevent loss of grout at the face, the Contractor may at his own expense add rapid hardening agent to the grout. The amount added shall be subject to the approval of the Engineer and shall normally be such that the initial setting time of the grout is not less than 5 minutes.

24.7.6. Secondary Grouting of Tunnel Rings
Cement and water shall be mixed in high speed colloidal mixers until they form uniform slurry. Thereafter, mixing shall continue at slower speed until that mix is used up or grouting is complete.

The grout shall be pumped using a positive displacement pump capable of pumping slowly at a specified pressure with excess grout being returned by means of an adjustable pressure relief valve to the mixer.
Secondary grouting shall not commence until at least 3 days after any cavity
grouting (excluding cavity grouting of steel lining to tunnels) and all sealing of
caulking grooves, etc. have been completed.

Holes shall be opened over the length of tunnel to be grouted. Alternate rings shall
have holes drilled in them, three holes to a ring, at 120° spacing. The holes shall be
staggered so that every fourth ring has a hole in the crown and the intermediate drilled
ring has a hole in the invert. The holes shall be taken through any cavity grout and shall
have all loose material cleaned out. Each hole shall be fitted with a temporary pipe,
valve and coupling for the injection of grout, these being firmly fixed before grouting
start.

Grouting shall start away from the shaft and work towards it. Initially, the
water/cement ratio of the grout shall be about 1/4 unless the Engineer directs otherwise.
A complete pass shall be made with this grout at a pressure of about 2.5 bar, grout
being injected through each valve. Each valve shall be closed only when grout flows
continuously out of the valve or no further grout is being taken. As soon as the first
pass is complete, a second pass shall be made, using grout with a water/cement ratio of
about 1/2 or as directed by the Engineer. Grouting shall continue at each hole until no
further grout is taken. Any leakage through joints between segments shall be sealed by
ramming in caulkling compound or lead wool or other approved method.

The grout pipes, valves and couplings shall be removed as soon as trials show that
this can be done without loss of grout. The holes in the rings shall then be made good
with stiff cement mortar and finished smooth.

24.7.7. Contact Grouting

No earlier than 28 days after a concrete lining has been placed in a tunnel, contact
grouting shall be carried out as a continuous process commencing at one end of the
tunnel and advancing towards the other end.

Holes shall be drilled through the concrete 150mm into the rock at regular
intervals and at other points where the lining gives indications of voids. Air release
pipes fitted with plug cocks extending to rock shall be built into the holes through
which grout injections are to be made.

A 1:3 sand-cement mixture having a bleed of less than 5% as determined by ASTM
Test C243-85 shall be injected at a pressure not exceeding 300 KN/m² measured at the
point of injection and the operation continued until no further grout is accepted. The
Contractor shall incorporate bentonite or other additive directed by the Engineer into
this mix if such additive shall be found necessary to reduce the bleed of the mixture to
less than 5% Holes drilled prior to grouting shall be plugged.

Once the grout has set, the Contractor shall return and redrill adjacent to every
original fourth hole and inject a cement grout having a water/cement ratio of 0.55:1 by
weight and if necessary repeat this process until the Engineer is satisfied that the
operation of contact grouting has been thoroughly completed and there are no voids left
along the interface between the concrete of the lining and the rock surface of the tunnel.

The Contractor may be required to carry out water tests on completion of the
contact grouting procedure. The pressures to be adopted shall not exceed the maximum
grouting pressure by more than 25%.

The system of contact grouting behind steel tunnel lining shall be carried out in a
similar manner to that specified for concrete linings but at maximum pressure
determine by the Engineer for each section of the tunnel. The steel linings shall be
fitted with special screwed openings through which the drilling and grouting shall be carried out. After completing the cavity grouting the steel plugs will be screwed into the steel lining and welded circumferentially. Finally the plug and weld will be ground flush with the steel lining.

24.7.8. Fissure Grouting Procedure

The closure method of grouting shall be adopted wherever practical. In this method, an additional drillhole is located mid-way between two previously grouted holes. Grout holes shall be designated as primaries, secondaries, tertiaries, etc.

Unless authorized by the Engineer, primary hole grouting shall be advanced at least 10 m ahead of secondary hole grouting and so on for each phase of grouting.

Generally, grouting of each stage will be started with a thin mix having a water/cement ratio of 3:1 by weight and the mix shall be thickened progressively in accordance with the variation in the pumping rate and pressure during the course of the injection. Each mix shall be injected for at least 5 minutes before being thickened unless the hole is known to have intersected a cavity or wide fissure in which case the mix shall be thickened more rapidly. Unless refusal is achieved on a thinner mix, injection shall continue using a mix having a water/cement ratio of 1:1 by weight until refusal is achieved.

Bentonite shall, unless otherwise directed by the Engineer, be incorporated in all cement grout mixes having water/cement ratios of 1:1 or higher by weight as an additive to assist suspension of cement particles. The dry weight of bentonite added shall, subject to grout tests, be equivalent to 2.5% of the weight of cement in each mix. Other additives shall be incorporated in grout mixes as my be required by the Engineer.

Grouting shall be terminated in each stage (at refusal) when the grout takes over ten minutes period is not greater than 2.5 liter per meter length of the stage being injected.

Once the grouting of a stage has been started, it shall be continued as far as is reasonably practical without interruption until refusal is achieved. Should it be necessary to interrupt an injection before it is complete (for instance if there is a plant breakdown) about 500 liter of clean water shall be run into the hole before it is allowed to stand.

Pressures used for grouting are subject to the Engineer’s approval. The minimum grouting pressure shall be 2 bars which shall be continuously monitored by suitable gauges. If grout take is low, the grouting pressure shall be increased at steps of 1 bar up to a minimum pressure of 5 bars. All grouting procedures may be varied by the Engineer to take account of the conditions encountered and the injections previously measured.

If, due to the size and continuity of fractures, it is found impossible to reach the required pressure after pumping a reasonable volume of grout at the minimum workable water/cement ratio, then a 1:3 sand-cement mixture shall be injected. If this grout mix does not make it possible to reach the required pressure the speed of pumping shall be reduced. If directed by the Engineer the grout shall be allowed to attain initial set, the hole shall be cleaned out, after final set of the grout additional drilling and grouting shall be undertaken in this hole or in the adjacent area. If, during the grouting of any hole, grout is found to flow from adjacent holes in sufficient quantity to interfere seriously with the grouting operation or to cause appreciable loss of grout, the holes through which significant leakage occurs may be capped.
temporarily. Where such capping is not essential, ungrouted holes shall be left open to facilitate the escape of air and water as the grout is forced into the holes but covered to prevent entry of debris and spillage. Before the grout has set, the grout pump shall be connected to adjacent capped holes and to other holes from which grout was observed, and grouting of all such holes shall continue as directed by the Engineer. After the grouting of any stage of a hole is finished, the pressure shall be maintained by means of a stop-cock or other suitable device until the grout has set to the extent that it will be retained in the hole.

Fouling of the equipment and lines shall be prevented by the constant circulation of grout and by the periodic flushing out of the system with water. Flushing shall be undertaken with the grout intake valve closed, the water supply valve open, and the pump running at full speed.

In stage or stage and packer grouting, the hole shall be cleaned out in a manner to be agreed with the Engineer before drilling for the stage to follow. In cases where the Engineer decides that the hole can be cleaned out by washing, the Contractor shall either clean out the hole before the grout has set sufficiently to require re-drilling or if he fails to clean out the hole before the grout has set, shall re-drill.

24.7.8.1. Equipment for Chemical Grouting

If the amount of infiltration exceeds the facilities of a cement grout the water bearing joints shall be sealed by chemical components such as epoxy resins which foam in the presence of water or polyurethane.

The Contractor shall supply all necessary equipment including the chemicals, such as:
- Packers either to be glued on the surface or to be installed in drilled holes including special head valves.
- High pressure pump yielding pressure up to 250 bar
- Epoxy resin, chemical foam
- Appropriate drilling equipment

The chemical components shall be used for a provisional stemming at a first stage and a deeper seated grouting at a second stage. The surface sealing shall be performed with one component chemical foam, which reacts immediately with the water and bars the infiltration.

24.7.9. Procedure of Chemical Grouting

The packer shall be either glued on the surface by means of epoxy resin or tensioned in a drill-hole and the surface shall be stemmed as described above. The drill-hole shall pass the water bearing joint at an angle of 45.

The chemical grout shall be injected at pressures between 50-bar and 200-bar to seal the joint.

24.7.10. Documentation

At each grouting site the Contractor shall maintain a record of his work which includes the following
- date, chainage
- yield of water, width and length of the joint
- type and number of packer as well as their spacing
- depth, number, size, inclination and direction of the drill hole
24.8. In Situ Concrete Lining

24.8.1. Preparation for Concrete Lining

The Contractor shall thoroughly clean the underground works of all objectionable coatings, loose or unsound bedrock fragments, track ballast, mud, debris and standing water before concrete linings are placed, satisfactory arrangements shall be made, subject to the approval of the Engineer for leading away springs of water in pipes or otherwise through concrete linings.

24.8.2. Placing Concrete

Concrete in tunnel and shaft linings, and in other underground works, shall have a strength of 40 MPa except where otherwise specified or directed by the Engineer. Concrete shall be mixed and transported in accordance with Section 10, “Concrete Structure” in these specifications and shall be pumped or placed with pneumatic placer, and compacted by the use of internal vibrators. Concrete in walls and arches shall be brought up in horizontal layers, or otherwise as may be approved by the Engineer, between vertical construction joints. Concrete in shafts may, subject to the approval of the Engineer be placed continuously behind climbing shutters.

For pumped or pneumatically placed concrete, the discharge and of the supply pipe shall, as soon as possible during a placing operation, be kept immersed in concrete already placed. The placing of concrete shall be carried out as rapidly as possible once a pour has been commenced, and the Contractor shall take all measures necessary during placing to prevent the formation of cold joints or other defects. At the beginning of a pour the concrete proportions shall, if found necessary, be varied by the omission of a proportion of coarse aggregate, so as to form a satisfactory joint with previously placed concrete. Concrete shall not be pumped or projected into the crown or arch of tunnels and be allowed to flow into walls.

No concrete shall be placed in underground works closer than 50 m from a where excavation with explosives in progress.

24.8.3. Concrete in Tunnel Inverts

Concrete in tunnel inverts and foundations to tunnel walls shall be placed on bedrock or on clean sound well-compacted rock spoil. The minimum thickness of concrete in tunnel inverts shall not be less than 150 mm. at sections not exceeding 50m apart the whole width of concrete shall be founded on bedrock for a length of 1.5 m or alternatively the rock spoil shall be contact grouted at these sections.

Where invert concrete is laid on compacted rock spoil, building paper or polythene sheeting 0.1 mm thick shall be placed on the spoil immediately before concrete is placed, where ordered by the Engineer.

24.8.4. Formwork to Tunnel and Shaft Lining

Formwork for concrete placed in tunnels, shafts, transitions, bends and other underground works shall be strong, accurately set and rigidly held to the prescribed alignment. Formwork for tunnels and shafts shall comprise purpose-made steel shutters.
capable of being used many times. Tunnel formwork shall be provided with inspection doors at approximately 2 m intervals on both sides. For bends, transitions and other non-repetitive work, purpose-made timber formwork will be acceptable. After concreting has been completed, tunnel lining shutters shall be left in place until they can be removed without detriment to the concrete. The minimum time for removal shall be approved by the Engineer.

24.8.4.1. Construction Joints

Except where specified otherwise, construction joints in underground concrete works shall be formed square to the line of tunnel or shaft. In tunnels, construction joints shall as a general rule be at least 15 m apart. The details and positions of all construction joints shall be subject to the approval of the Engineer.

24.8.5. Filling Over-break

Over-break in tunnels and shafts shall be any excavation outside the clearance line.

In lined sections where steel ribs are not being used, over-break less than 300 mm from the clearance line shall be filled with the same class of concrete as the lining and placed integrally with the lining. Over-break more than 300 mm from the clearance line may be filled with concrete, or cement grout or grouted rock fill at the discretion of the Engineer.

In unlined or sprayed sections where there is over-break more than 1 m from the clearance line the Engineer may require the over-break to be filled with suitable class concrete, or cement grout, or grouted rock fill. This filling shall be faced with 300 mm of Class A, B or C concrete or as directed by the Engineer.

At the discretion of the Engineer, over-break in tunnel invert may be refilled with compacted coarse aggregate or tunnel spoils where the tunnel is in sound rock.

Filling over-break in sections of tunnel where steel ribs are used shall be in accordance with Article 24.6.2.2.

24.8.6. Drilling and Grouting

Drilling, contact grouting and fissure grouting of tunnel and shaft linings shall be carried out as specified for Grouting.

24.9. THE METAL LINING

24.9.1. General

The Contractor shall provide and install the metal lining in accordance with the details shown on drawings.

Lining metal must be electric fusion welded or welded spiral compass healing and carbon tube plant in accordance with the BS 3601. Iron must be of class X 42 and must be compatible with the requirements of API SL system and minimum thickness described in the drawing.

The Contractor shall deliver two copies of the certificate of steel plant, which must show that the iron used in accordance with the requirements.
24.9.2. Internal protection

The Contractor shall deliver his proposals for the interior protection system intended to be used and must receive the approval of the engineer before handing over his request for the metal lining.

The age of the protection system must be at least 10 years. Protection system should consist of paint with paints of epoxy-based. Before applying any paint the inner surface of the lining must be cleaned by blowing according to the BC 4232 system, second quality, (perhaps equivalent to system SA 2.5 in Swedish standard SIS 05 5900) to remove all scales resulting from the mining process and contaminated materials other than the bottom layer of mineral and until approval of the engineer can be done. All remnants Libel / sandstone must be removed and a single layer packaging of additional zinc and raw layer protection based on epoxy must be sprayed directly using pneumatic gun. Dry thin layer of the initial layer must be at least 25 microns. Later, at least two layers of paint with epoxy base layer should be applied, which gives a final solid non-toxic and chemical-resistant and must be applied using anaerobic spray. The dry thin layer thickness should be as a minimal value 50 microns.

Unless authorized in writing by the engineer, the contractor must, the protection of the inner part of the metal lining, should be comply with the manufacturer's instructions for paint dramatically.

24.9.3. Outside protection

Metal lining must be delivered with outside protection applied in the laboratory, which must bear the effects of the storage environment and protect the metal substrate in the period prior to the installation of the lining. The Contractor shall deliver his proposals for external protection system before to deliver his materials of metal for lining.

24.9.4. Shipping and packaging and storage

Contractor must do all the necessary arrangements for on-site storage for the entire metal lining. The contractor should not remove any protection materials that was used in transferring of the metal lining so that the inner lining of metal ready to put in place. Care should be taken every time through the packaging to make sure that the lengths of the lining are supported so that it not gets excessive distortions.

24.9.5. Exposure

Contractor shall control the storage time and the rate of installation of the lining of metal, so that any length of the lining metal should not stay more than six months exposure to the environmental weathering effects, in this period the contractor should raise lining a distance of 100 mm from the ground.

24.9.6. The Situation

Before putting any length of the lining in the ventilation shaft, it should make a thorough examination and affected lengths should be done well in accordance with the supplier instructions or as directed by the engineer, external surfaces should be cleaned of dirt and rust in addition of oil and fat. The difference between the maximum internal diameter and minimal in any section should not exceed 0.75% of the internal diameter. When it is necessary, the lining must be supported from the inside to maintain the circular shape even after connecting. At joints, should not be deference between the two lining more than 2 mm at any point along the link.
24.9.7. Welded Joints
For effective welding of not less than 90%, any joints should be welded at the site in accordance with BS 4515.

24.9.8. Examination of welded joints
Any welded joints in the site for lining, should be examined separately using ultrasonic waves by a qualified independent testing to give consent. Welded Joints in which slots or runoff must be inferred and must be re-welded and re-examined until the approval of the engineer.

24.9.9. Injection Arrangements
Metal lining should be provided with the metal injection holes for cavity injection or direct. The Contractor shall put direct mortar on the contact surface between metal lining and rock. Mortar supplying pipes, should be of metal tubes of medium thickness and 40 mm hollow according to BS 1387 system with sparks BSP to BS21, and must be provided by the contractor. Each slot injection must be equipped with 20 mm thick cuneiform stopper that are fitted with the metal lining, and this must be removable plugs easily.

The thickness of slot injection should not be less than 25 mm. Metal humps should be welded with 100 mm in diameter to the outside of the metal lining to make the total thickness comply with the minimal requirements.

Injection nozzles must be in groups of three at a 120 degree angle between each two of them. Should not diverge openings groups from each other for more than 1.5 m, and in each the length of the metal lining, it must supply a set of holes at a distance of 0.3 m from each end.

After completion the injection process and after beginning initial sclerosis of mortar, clogs must be placed and proved well in place by the contractor. Clogs heads must be placed decline of 6 mm from the inner face of the metal tube. Plugs must be sealed with a layer of weld metal thickness 6 mm above the head of the stopper, and metal welding settled to the inner face of the tube.

24.10. Major Tunneling Equipment and Their Specific Uses

24.10.1. Shield Tunnels
Tunnels in loose, non cohesive or soft ground are generally driven by means of a steel shield; most often circular in shape, either in free air or, if necessary, under compressed air. The shield permits the excavation of soil and the erection of primary lining under safe conditions; allows better control or ground settlement; and is a must in subaqueous tunnels. Soil conditions requiring shield construction generally are:
1. Weak non-cohesive soils like running sand and loose gravel or silt which are practically cohesion - less and which, cannot be safely and efficiently excavated by ordinary soft ground tunneling techniques, can be handled by the use of a shield.
2. Soft plastic clays, particularly those with critical water content and which become easily liquefied when worked, call for shield excavation.
3. For tunneling below ground water level, a shield is required unless the ground water can be lowered or the soil is solidified by injection.
24.10.1. Open shields

This shield has an open working face, divided only by the bracing and is used in soil which is firm enough to stand or which can be held by breasting. It usually consists of circular steel cylinder with stiffening ribs and bracing to withstand the external pressure. The circular shape permits erection of lining segment.

24.10.1.2. Closed Shields

In very soft clay or silt or fine running sand, the front face of the shield is closed by a solid steel bulkhead. This is equipped with ports through which the soil is excavated and removed. The ports can be closed with steel doors. The bulkhead is braced with steel ribs, welded to the body to resist the soil pressure.

24.10.1.3. Half shields

Semi circular or semi ellipsoid shields are some times used to support the roof of a tunnel during excavation in dry or dewatered ground. This may apply to a tunnel at shallow depth where open excavation is not permitted or practical. The shield is supported on temporary steel beams set on steel posts or concrete side walls.

24.10.2. Tunnel Boring Machines (TBM)

A Tunnel Boring Machine generally is a device for excavating a tunnel in such a way that the material to be removed is disintegrated by the continuous rotation of a group of cutting tools thrust against the surface of the material at the working face.

All tunneling machines incorporate tools for breaking up the material to be excavated into size that can easily be removed. In most but not in all, machines, the full cutting head is employed. The cutting tools are mounted in an arrangement suitable to excavate a tunnel of the required diameter when the head is rotated under thrust against the working face.

The machine body is mounted immediately behind the cutting head and remains stationary while the cutting head excavates. It incorporates a mechanism to maintain its stationary position during excavation and to move itself and the cutting head forward to continue the excavation. The machine body also contains the mechanical equipment to provide the necessary thrust and torque transmitted through the cutting head to the cutters.

In most cases muck is removed from the excavated face by a number of buckets on the cutting head and dropped onto a conveyor belt system. It then passes on a series of conveyors to the back of the tunneling machine where it discharges into another transportation system for removal from the tunnel which is usually entirely independent of the tunneling machine.

In soft ground machines, the main function of the forward thrust generally is to support the vertical face of the excavated ground against collapse along with the segment lining installation whereas in rock tunneling machines the thrust is to supply the energy to disintegrate the material.

24.10.3. Drilling and Blasting Method

Most underground hard rock excavation requires excavation by drilling and blasting as this is the appropriate practical method.
24.10.3.1. Sequence of Operation

For a tunnel driven by drilling and blasting method through the rock the following operations may apply:

1. Setting up and drilling
2. Loading holes and blasting the explosives.
3. Ventilating and removing the dust following on explosion
4. Loading and hauling the muck.
5. Removing ground water if necessary
6. Erecting supports for the roof and sides if necessary.
7. Placing reinforcing steel
8. Placing the concrete lining.

For the equipments and their uses only items 1, 2, 4,5 and 6 shall be described here. Rest may be referred into the respective section dealing with them.

1. Drill Mountings for Small Tunnels

Drills used in small tunnels are mounted on bars or columns which are made from sections of steel pipe equipped with a column. Bars are installed horizontally in a tunnel whose width is less than the height, while columns are installed vertically in a tunnel whose height is less than the width.

2. Drill Jumbos

A drill jumbo is a portable carriage with one or more working platforms, equipped with bars, columns or booms to support the drills. The supports are designed to permit the drills to be spaced to any desired pattern. The drilling equipment is hydraulic or air powered boom to support rock drills.

3. Mucking

The operation of loading broken rock or earth for removal from a tunnel is referred to as mucking. This operation may be performed by power shovels, mucking machines slushers or tractor loaders.

Special power shovels, with short booms and dipper sticks have been used for mucking in large tunnels. If ventilation is not a serious problem, a gasoline or diesel – engine powered unit may be used. If the exhaust fumes are objectionable a unit powered with an electric motor is used. Several mechanical mucking machine operate on rails, moves forward to push the dipper into the piles of muck. When the dipper is filled, the machine backs up a short distance and tips the dipper up to discharge the load onto a belt, which conveys it back to a muck car, attached temporarily to the mucking machine.

4. Hauling Muck

Many times muck is hauled from a tunnel in narrow gauge muck cars, pulled by locomotives, or in trucks. Also dumper trucks are used in increasing numbers to haul muck form tunnels.

5. Trucks

When muck is hauled in cars, steel rails are required. For this relatively light weight rails are laid to a narrow gauge. For a long tunnel it is necessary to provide a double track in orders that loaded cars may be moved out while empty cars are moved into the tunnel.
6. Muck Cars

Various types and sizes of cars are used to haul muck from tunnels. The capacity may be expressed in cubic meters. In general, the largest size that can be used in a tunnel will be most economical, as large cars reduce the time lost in switching at the loading operation. The cars are commonly used at the bottom to permit easy dumping.

7. Locomotives

Three types of electric locomotives are available for tunnel hauling: trolley, battery and combination trolley and battery. All are available in various weights and for operation on different track gauges, as indicated by the manufactures.

24.11. Measurement and Payment

24.11.1. Items to Be Included in Rates

All works for which no item is provided in the Bill of Quantities are deemed to be included in the unit rates. These items include but are not limited to the following:

- Connecting of water, gas, electricity from the mains on the site indicated by the Engineer to the point of use.
- Provide sufficient illumination for the execution and inspection of works, i.e. one (1) lamp per 20 m containing a bulb of 100 Watt in a watertight case.
- Transport of all material and building components, even if ordered by the Engineer, from the stores on the Site to the point of use, and possible return transport.
- All setting-out and survey works according to the Specifications as approved and/or directed by the Engineer.
- All tests and samples of materials used according to Standards as specified in the Technical Specification or as directed by the Engineer.
- Securing all works against surface water which is normally to be expected (25 years return period) and its removal.
- Protecting of the placed shotcrete against heat, wind, cold, chemical attack, vibration and drying out.
- Removal of all rebound material and all other debris resulting from the Contractor’s operation.
- Unless otherwise specified herein all and any kind of work materials, services, safety measures etc.
- Sufficient ventilation to safeguard the health of the personal.
- Communication such as telephone, sound or visual system.
- Gas detection

24.11.2. Underground Excavation in Tunnels

Excavation shall be measured to the Clearance Line and no payment will be made for excavation outside the Clearance Line.

The Contract Rates for underground works shall include for disposal of excavated material, over break less than 3.0 m$^3$ and for any pilot drilling required.

Where, with the approval of the Engineer excavation is carried out by forepoling or by the use of a shield the additional costs shall be deemed to be included in items for excavation except where items are specifically included for this work.
The costs of constructing and backfilling any temporary adits, passing bays, safety niches and the like constructed by the contractor shall be deemed to be included in the contract rates for underground excavation.

The costs of removal of soil and rock deposited by earth and rock falls and the backfilling of resulting overbreak shall be deemed to be included in the contract rates for underground excavation.

Washing down excavation for inspection shall be measured by area. Only areas washed down upon the order of the Engineer shall be measured and payment will not be made when rock faces are washed down for other purposes.

Temporary support shall be measured for payment only where it has been approved by Engineer. It shall not be measured for payment, even where it has been approved, where it is:

1. Used to support material which is inside the clearance line;
2. Used to support the temporary face of an advancing excavation, or
3. In the opinion of the Engineer made necessary by reason of the contractor’s neglect.

Photographic profiles of the tunnel cross section shall be prepared where directed by the Engineer and shall be measured by number.

The measurements will be made to the nearest cubic meter.

The unit rate for any type of underground excavation shall include all costs of supply operation, maintenance and repairs of equipment, fuel, labor, all auxiliary works, lighting, ventilation, transportation and dumping of muck in designated spoil banks, disposal of water up to 1 liter/sec per 100 m of tunnel, niches, lay bays etc.

24.11.3. Removal of Cave-In and Geological Overbreak

The measurement for geological overbreaks and cave-ins resulting from no fault of the contractor shall be made by cross-sections to be prepared by the contractor and approved by the Engineer, as the volume occupied by the rock in its undisturbed state before collapse.

The rate quoted in the contract is deemed to include all costs of removal to spoil banks.

Volumes less than 3.0 m$^3$ at any one location will not be measured.

24.11.4. Structural Steel Supports

Measurement for steel arch supports and steel lagging if any shall be made by the weight installed. In the case of wooden wedging or blocking the rate is deemed to be included in the rate of steel and the wood used will not be separately measured.

Only the weight of steel shall be calculated by any of the recognized tables or by actual weight of a measured length of steel section or other elements used.

The unit rate for structural steel supports includes all costs of supply, preparation, equipment installation, fuel, labor, auxiliary works, preparing stable foundation for steel arches and wood used in wedging.

24.11.5. Rock Bolts

Specified length of rock bolts shall be measured from the under side of the bearing plate. Measurement, for payment, of grouted and ungrouted rock bolts will be made per number of approved rock bolts installed. Pullout, tensile tests performed on installed rock bolts shall indicate whether rock bolts are accepted (120 per cent of nominal load.)
The unit rate for grouted and ungrouted rock bolts shall include all cost of supply operation, maintenance and repair of equipment, spare parts, drill set-up, material, fuel labor and all auxiliary works required to perform the work as set out in the technical specifications. Further, the unit rate shall include flushing and cleaning of the anchor hole after drilling, maintaining the holes free from obstructions till placing of the anchor, grouting and all identical work connected herewith. All expenses caused by standard pull out tests and the tensile tests shall also be included in the unit price.

24.11.6. Reinforcement for Shotcrete

Measurement, for payment, of reinforcement of shotcrete will be made according to the weight of fabric mesh reinforcement steel or reinforcement steel bars placed as specified and directed by the Engineer. The weight of steel will be measured to the nearest kilogram. No measurement will be made for supports required for the fixing or distribution of the reinforcement.

The unit rate for reinforcement shall include all cost of material, labor, support materials, cutting and bending, scaffolding and all other work required for the installation of the reinforcement. No payment will be made for reinforcement that has been placed without the Engineer’s previous instruction.

24.11.7. Shotcrete of 50, 100, 200 & 250 mm Thickness

Measurement, for payment, of shotcrete will be made along the clearance line of the tunnel as shown on the Drawings and as specified in the section for excavation and according to the Engineer’s written instruction of location, extent and thickness of shotcrete to be applied.

In tunnel sections with geological overbreak the measurement will be made according to the actual surveyed sections approved by the Engineer.

The quantity of the shotcrete will be measured to the nearest square meter. However, if the strength of shotcrete and the thickness of the layers do not comply with the specified works, the quantities shall be reduced by the Engineer.

The unit rate for any class of shotcrete shall include all cost of supply, operation, maintenance and repair of equipment, spare parts, material including additives, fuel, labor, batching, placing, curing, testing and all auxiliary work required to perform the works as set out in the Technical specifications. The unit rate of shotcrete shall over also all expenses for the installation of steel bars required to determine the layer thickness. No extra shall be paid for difficult work conditions, ground water, or for different locations within the tunnels.

24.11.8. Concrete Lining

Measurement of concrete lining shall be made to the clearance line shown on the drawings. No additional payment shall be made for infilling of over-excavated areas.

The unit rate shall include cost of all material, operation of machines and equipment, form work, care of water, embedded pipes, labor, fuel and auxiliaries.

24.11.9. Reinforcement in Tunnel Lining

Reinforcement shall be measured as the weight of reinforcement bars placed in the tunnel. The weight shall be determined by the total length of bars, their diameter and standard weight per unit length as per charts.
The unit rate shall include supply, bending, placing, binding with wire, and all other operations of machine, equipment, transportation, fuel, labor, auxiliary works etc.

24.11.10. Convergency Measurements
Measurement will be as per one instrumented section of the tunnel.
The unit rates shall include all preparations, use of equipment, supply of measuring devices and the actual observation of deformations.

24.11.11. Care of Water In Excess of 1 liter/sec
The contractor shall quote a price for provision of dewatering capacity more than 1 liter/sec per 100 m of tunnel including supply and maintenance of energy, submersible mud pumps, hoses, couplings, pipes etc. the quantity of water shall be measured by any recognized method of a weir, venture meter or of a jet issuing from a pipe of known diameter at the point of final disposal.
Measurement shall be made of continuous flow only.
Payment shall be made in monthly installment as a monthly item.
The item is payable only if the discharge exceeds 1 liter/sec for 100 m of tunnel where work is in progress and not as the sum of discharges from the working areas over which the work may be spread.

24.11.12. Grouting Works (Excluding Cavity Grouting)
The cost of supply and the maintenance of the grouting equipment as well as energy, spare parts and documentation shall be included in the grouting works below.
The shifting from one point of application as well as setup and removal are covered by a separate item. Setting up shall be measured only once for each setting up of all equipment to start grouting at a new hole. Setting up shall in addition be measured where the Engineer orders grouting equipment to be returned to a previously grouted hole for additional grouting. Setting up shall not be measured unless grouting is undertaken at the hole.
All drillings shall be refunded as per linear meter. Drilling shall not be measured for any hole length which cannot subsequently be used for the intended purpose for any reason.
The supply and installation of packers for cement grout has to be included in the time of grouting.
The grouting works shall be paid as by hour of grouting and the components of the mix as by weight.
The supply and installation of packers for the chemical mix shall be included in the unit price of the chemicals.
Payment will be made as indicated in Table 24.2. And the quality control requirements for concrete tunnel liners are shown in Table 24.3.

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>24.1</td>
<td>Steel and Concrete Tunnel</td>
<td>Linear Meter</td>
</tr>
</tbody>
</table>
### Table 24.3: Quality Control Requirements For Concrete Tunnel Liners

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Excavation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disposal of excavated material</td>
<td>Visual observation</td>
<td>--------</td>
<td>--------</td>
<td>Article 24.5.4</td>
<td></td>
</tr>
<tr>
<td>Excavation for bolted ring tunnels in soft ground</td>
<td>Observation the contractor shield and measurement the advance beyond ring</td>
<td>--------</td>
<td>Each</td>
<td>Article 24.5.5</td>
<td></td>
</tr>
<tr>
<td>Excavation through weak weathered rock</td>
<td>Observation the excavation advance and drainage the ground water</td>
<td>--------</td>
<td>--------</td>
<td>Article 24.5.6</td>
<td></td>
</tr>
<tr>
<td>Excavation through generally prevailing rock</td>
<td>Observation a smooth blasting and cleaning surface of rock and supporting walls and vaults</td>
<td>--------</td>
<td>--------</td>
<td>Article 24.5.7</td>
<td></td>
</tr>
<tr>
<td><strong>Supports</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolted concrete rings</td>
<td>Conformity of requirements of pre-cast reinforcement concrete</td>
<td>In situ</td>
<td>Each</td>
<td>Article 24.6.1</td>
<td></td>
</tr>
<tr>
<td>Erection of bolted ring</td>
<td>Erection observation</td>
<td>In situ</td>
<td>Ring by ring</td>
<td>Article 24.6.1.1</td>
<td></td>
</tr>
<tr>
<td>Steel supports</td>
<td>Approval the type, size, locations, and spacing of members and method of placing</td>
<td>--------</td>
<td>--------</td>
<td>Article 24.6.2</td>
<td></td>
</tr>
</tbody>
</table>

### 24.12. References

AASHTO LRFD Bridge Construction Specifications Second Edition. 2004

SECTION 25. STEEL CULVERTS

25.1. General

25.1.1. Description
This work shall consist of furnishing, fabricating, and installing metal pipe, structural plate metal pipe, arches, pipe arches, and box structures in conformance with these Specifications and the details shown in the contract documents. As used in this specification, long-span structures are metal plate horizontal elliptic, inverted pear and multiple radius arch shapes, as well as special shape culverts as defined in Section 10 of the (MA-100-D-V1/2 & V2/2).

25.2. Working Drawings
Whenever specified in the contract documents, the Contractor shall provide Manufacturer's assembly instructions or working drawings and substantiating calculations in sufficient detail to permit a structural review of the structural design. The working drawings shall be submitted in advance of construction to allow for their review, revision, and approval without delay to the work.

The Contractor shall not start the construction of any metal culvert for which working drawings are required until the drawings have been approved by the Engineer. Such approval will not relieve the Contractor of responsibility for results obtained by use of these drawings or any other contractual responsibilities.

25.3. Materials

25.3.1. Corrugated Metal Pipe
Steel pipe shall conform to the requirements of AASHTO M 36 (ASTM A 760/A 760M), and shall be fabricated from either zinc-coated steel sheet or aluminum-coated steel sheet except when fabrication from zinc-coated steel sheet is required by the special provisions.

Zinc-coated steel sheet shall conform to the requirements in AASHTO M 218.

The pipe type and corresponding AASHTO designations are shown in Table 25.1:

<table>
<thead>
<tr>
<th>Pipe Type</th>
<th>AASHTO Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular</td>
<td>Type I</td>
</tr>
<tr>
<td>Circular, smooth-lined</td>
<td>Type IA</td>
</tr>
<tr>
<td>Circular, spiral rib</td>
<td>Type IR</td>
</tr>
<tr>
<td>Arch</td>
<td>Type II</td>
</tr>
<tr>
<td>Arch, smooth-lined</td>
<td>Type IIA</td>
</tr>
<tr>
<td>Arch, spiral rib</td>
<td>Type IIR</td>
</tr>
</tbody>
</table>

Corrugated metal pipe of all types shall be provided with annular corrugations, helical corrugations, or spiral ribs (corrugations) projecting outward.
Pipe with helical end corrugations shall be provided only when necessary to join new pipe to existing pipe with helical end corrugations.

For pre-coated galvanized steel pipe, a minimum polymer coating thickness of 300 µm shall be provided on each side.

25.3.2. Structural Plate

Steel structural plate shall conform to the requirements of AASHTO M 167M/M 167 (ASTM A 761/A 761M).

25.3.3. Nuts and Bolts

Nuts and bolts for steel structural plate pipe, arches, pipe arches, and box structures shall conform to the requirements of AASHTO M 167MfM 167 (ASTM A 761/A 761 M).

25.3.4. Mixing of Materials

Steel materials shall not be mixed in any installation unless the materials are adequately separated or protected to avoid galvanic reactions.

25.3.5. Fabrication

Plates at longitudinal and circumferential seams shall be connected by bolts with the seams staggered such that no more than three plates come together at anyone point.

25.3.6. Welding

If required, welding of steel shall conform to the current AASHTO/AWS D 1.5M/D 1.5 Bridge Welding Code. All welding of steel plates, other than fittings, shall be performed prior to galvanizing.

25.3.7. Protective Coatings

When required in the contract documents, metal pipes and structural metal plate culverts shall be protected with bituminous coating or have the invert paved with bituminous material. Bituminous coatings shall be applied as instructed in AASHTO M 190, Type A, unless otherwise specified in the contract documents. If required, bituminous pavings shall be applied over the bituminous coatings to the inside bottom portion of pipe as provided in AASHTO M 190, Type C, unless otherwise specified in the contract documents. The portion of all nuts and bolts used for assembly of coated structural plate pipe, arches, pipe arches, and box culverts, projecting outside the pipe shall be coated after installation. The portions of the nuts and bolts projecting inside the pipe need not be coated.

When required in contract documents, polymeric coatings shall conform to the requirements of AASHTO M 246 (ASTM A 742/A 742M). The polymeric coating shall be applied to the galvanized sheet prior to corrugating and, unless otherwise specified in the contract documents, the thickness shall be not less than 0.25 mm. Any pinholes, blisters, cracks, or lack of bond shall be rejected. Polymeric coatings are not permitted on structural plates.
25.3.8. Bedding and Backfill Materials

25.3.8.1. General

Bedding shall be loose native or granular material with a maximum particle size less than one-half the corrugation depth. Backfill for metal culverts shall be granular material, as specified in the contract documents and specifications, and shall be free of organic material, rock fragments larger than 75 mm in the greatest dimension, and frozen lumps, and shall have moisture content within the limits required for compaction. As a minimum, backfill materials shall meet the requirements of AASHTO M 145 for A-1, A-2, or A-3.

25.3.8.2. Backfill Materials for Long-Span Structural Plate Structures

Bedding and backfill materials shall meet the general requirements of Article 25.3.8.1. As a minimum, backfill materials for structures with less than 3.6 m of cover shall meet the requirements of AASHTO M 145 for A-1, A-2-4, A-2-5, or A-3. Minimum backfill requirements for structures with 3.6 m or more cover shall meet AASHTO M 145 requirements for A-1 or A-3.

25.3.8.3. Box Culverts

Bedding and backfill materials shall meet the general requirements of Article 25.3.8. As a minimum, backfill shall meet the requirements of AASHTO M 145 for A-1, A-2-4, A-2-5, or A-3.

25.3.8.4. Concrete Backfill

At locations where pipe is to be backfilled with concrete as shown in the contract documents, the concrete backfill shall be constructed of minor concrete conforming to the provisions in Section 10, "Concrete Structures," except that minor concrete shall contain not less than 200 kg of cement per one cubic meter of concrete. The concrete to be used will be designated in the contract documents.

25.4. Construction

25.4.1. Assembly

25.4.1.1. General

Corrugated metal pipe and structural plate pipe shall be assembled in accordance with the Manufacturer's instructions. All pipes shall be unloaded and handled with reasonable care. Pipe or plates shall not be rolled or dragged over gravel or rock, and shall be prevented from striking rock or other hard objects during placement in the trench or on the bedding.

Corrugated metal pipe shall be placed in the bed starting at the downstream end. Pipes with circumferential seams shall be installed with their inside circumferential sheet laps pointing downstream.

Bituminous coated pipe, polymer coated pipe, and paved invert pipe shall be installed in a similar manner to corrugated metal pipe with special care in handling to avoid damage to coatings. Paved invert pipe shall be installed with the invert pavement placed and centered on the bottom.
Structural metal plate culverts and pipes shall be assembled and installed as specified in the contract documents and detailed erection instructions. Copies of the Manufacturer's assembly instructions shall be furnished as specified in Article 25.2. Bolted longitudinal seams shall be well fitted with the lapping plates parallel to each other. The applied bolt torque for 19 mm diameter (M20) high strength steel bolts (ASTM A 449) for the assembly of steel structural plate shall be a minimum of 0.135 kN.m and a maximum of 0.407 kN.m.

25.4.1.2. Joints

Joints for corrugated metal culvert and drainage pipe shall meet the requirements described herein.

1. Field Joints

Transverse field joints shall be of such design that the successive connection of pipe sections forms a continuous line free from appreciable irregularities in the flow line. In addition, the joints shall meet the general performance requirements described in Articles 25.4.1.2 through 25.4.1.2.4.

2. Joint Types

The contract document should specify either "Standard" or "Special" joints as appropriate for the requirements at hand.

3. Soil Conditions

Special joints should be specified when poor soil conditions are encountered.

4. Joint Properties

The requirements for joint properties shall be taken as specified in Table 25.2. The values for various types of pipe may be determined by a rational analysis or a suitable test.

The following design issues shall be considered in the design of, or selection of, pipe joints:

- Joint Overlap: Standard joints which do not meet the moment strength alternatively shall have a minimum sleeve width overlapping the abutting pipes. The minimum total sleeve width shall be as given in Table 25.2. Any joint meeting the requirements for a special joint may be used in lieu of a standard joint.

- Soil Tightness: No opening may exceed 25 mm. In addition, for all categories, if the size of the opening exceeds 3 mm, the length of the channel shall be at least four times the size of the opening. For non-erodible or erodible soils, the ratio of \( D_{85} \) soil size to size of opening must be greater than 0.3 for medium to fine sand or 0.2 for uniform sand; these ratios need not be met for cohesive backfills where the plasticity index exceeds twelve percent (12%). Alternatively, a joint which withstands 14 kPa hydrostatic tests without leakage shall be considered soil tight. Joints that do not meet these requirements may be made soil tight by wrapping with a suitable geotextile.

- Watertightness: The adjoining pipe ends in any joint shall not vary more than 13 mm in diameter or more than 38 mm in circumference for watertight joints. Watertightness may be specified for joints of any category where needed to satisfy other criteria. The leakage rate shall be measured with the pipe in place or at an
approved test facility. The tolerances indicated may be attained by proper production controls or by match-marking pipe ends.

<table>
<thead>
<tr>
<th>Joint Property</th>
<th>Nonerodible</th>
<th>Erodible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Condition</td>
<td>Standard</td>
<td>Special</td>
</tr>
<tr>
<td>Shear Resistance</td>
<td>2%</td>
<td>5%</td>
</tr>
<tr>
<td>Moment Resistance</td>
<td>5%</td>
<td>15%</td>
</tr>
<tr>
<td>Tensile Resistance up to 1060 mm dia.</td>
<td>0</td>
<td>22.2 kN</td>
</tr>
<tr>
<td>Tensile Resistance (1200 mm-2130 mm.), dia.</td>
<td>-</td>
<td>44.5 kN</td>
</tr>
<tr>
<td>Joint Overlap, minimum</td>
<td>260 mm</td>
<td>NA</td>
</tr>
<tr>
<td>Soil tightness</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

### 25.4.1.3. Assembly of Long-Span Structures

Unless held in shape by cables, struts, or backfill, longitudinal seams should be tightened when the plates are hung. Care shall be taken to align plates to ensure properly fitted seams prior to bolt tightening. The variation in structure dimensions before backfill shall comply with the following provisions:

- For horizontal elliptic shapes having a ratio of top to side radii of three or less, the span and rise shall not deviate from the specified dimensions by more than two percent.

- For arch shapes having a ratio of top to side radii of three or more, the rise shall not deviate from the specified dimensions by more than one percent of the span.

- For all other long-span structures, the span and rise shall not deviate from the specified dimensions by more than two percent, nor more than 125 mm, whichever is less.

When required by structural design, reinforcing ribs shall be attached to the structural plate corrugation crown prior to backfilling, using a bolt spacing of not more than 300 mm. Legible identifying letters or numbers shall be placed on each rib to designate its proper position in the finished structure.

When required for control of structure shape during installation, reinforcing ribs shall be spaced and attached to the corrugated plates at the discretion of the manufacturer with the approval of the Engineer.
25.4.2. Installation

25.4.2.1. General

For trench conditions, the trench shall be excavated to the width, depth, and grade shown in the contract documents.

Proper preparation of foundation, placement of foundation material where required, and placement of bedding material shall precede the installation of all culvert pipe. This work shall include necessary leveling of the native trench bottom or the top of the foundation material as well as placement and compaction of required bedding material to a uniform grade so that the entire length of pipe will be supported on a uniform base. The backfill material shall be placed and compacted around the pipe in a manner to meet the requirements specified.

Materials used for foundation improvements, bedding and structure backfill must have gradations compatible with adjacent soils to avoid migration. Where material gradations cannot be properly controlled, adjacent materials must be separated with a suitable geotextile.

All pipes shall be protected by sufficient cover before permitting heavy construction equipment to pass over them during construction.

25.4.2.2. Foundation

The foundation under the pipe and structure backfill shall be investigated for its adequacy to support the loads. A foundation shall be provided, such that the structure backfill does not settle more than the pipe to avoid down drag loads on the pipe.

The foundation must provide uniform support for the pipe invert. Boulders, rock or soft spots in the foundation shall be excavated to a suitable depth and backfilled with material compacted sufficiently to provide uniform bearing as shown in Figure 25.1.

![Figure 25.1: Pipe Installation Nomenclature.](image)

Where the natural foundation is judged inadequate by the Engineer to support the pipe or structure backfill, it shall be excavated to a suitable depth and backfilled with...
material compacted sufficiently to control settlements as shown in Figure 25.2 and Figure 25.3.

Foundation On Localized Soft Zone

Note: \( d = 40 \text{ mm per meter of fill over pipe, with 0.6 m maximum} \)

Figure 25.2: Foundation Treatment for Localized Soft Spots or Rock

Figure 25.3: Foundation Treatment for settlement Control

Where relatively large-radius inverts adjoin small radius corners or sides for sections such as pipe arches, elliptic pipe or underpasses, the foundation shall be designed to support the radial pressures exerted by the smaller radius portions of the pipe. The principal foundation support shall be provided in the area extending radially outward from the smaller radius areas.

Where settlement of the pipe is expected to be so large that the required grade under high fills will not be maintained, pipe may be cambered to prevent excessive sag. The amount of camber shall be determined based on consideration of the flow line, gradient, fill height, the compressive characteristics of the foundation material, and the depth to incompressible strata.
25.4.2.3. Bedding

When, in the opinion of the Engineer, the natural soil does not provide a suitable bed, a bedding blanket shall be provided with a minimum thickness of twice the corrugation depth.

Pipe arch, horizontal elliptic and underpass shapes with spans exceeding 3.6 m should be placed on a shaped bed. The shaped area should be centered beneath the pipe and should have a minimum width of one half the span for pipe arch and underpass shapes, and one third the span for horizontal elliptic shapes. Pre-shaping may consist of a simple "V" graded into the soil as shown in Figure 25.4.

\[ W = \frac{\text{SPAN}}{2} \text{ FOR PIPE ARCH AND UNDERPASS} \]
\[ W = \frac{\text{SPAN}}{3} \text{ FOR HORIZONTAL ELLIPSE} \]

Figure 25.4: Shaped Bedding for Large Pipe-Arch, Horizontal Ellipse and Underpass Structures.

25.4.2.4. Structure Backfill

1. General

Sufficient inspection and testing should be undertaken to be certain that the quality of the soil and the compactive effort obtained is as specified.

Backfill material shall meet the requirements of Article 25.3.8 and shall be placed in layers not exceeding 200 mm loose lift thickness to a minimum ninety percent (90%) standard density per AASHTO T99. Equipment used to compact backfill within 900 mm from sides of pipe or from edge of footing for arches and box culverts shall be approved by the Engineer prior to use. Except as provided below for long-span structures, the equipment used for compacting backfill beyond these limits may be the same as used for compacting embankment.

The backfill shall be placed and compacted with care under the haunches of the pipe and shall be raised evenly on both sides of the pipe by working backfill operations from side to side. The side to side backfill differential shall not exceed 600 mm or one-third of the rise of the structure, whichever is less. Backfill shall continue to not less than 300 mm above the top for the full length of the pipe. Fill above this level shall be embankment fill or other materials as specified to support the pavement. The trench shall be kept to the minimum width required for placing pipe, placing adequate bedding and side fill, and safe working conditions. Ponding or jetting of backfill shall not be permitted except upon written permission by the Engineer.

Where single or multiple structures are installed at a skew to the embankment, proper support for the pipe shall be provided. Support may be achieved with a rigid, reinforced concrete headwall or by warping the embankment till to provide the
necessary balanced side support. The figures below provides guidelines for warping the embankment, see Figure 25.5.

Arches, long-span structures and box culverts may require special shape control, according to the manufacturer requirements, during the placement and compaction of structure backfill.

Figure 25.5: End Treatment of Skewed Flexible Culvert.

2. Long-Span Structural Plate Structures

Equipment and construction procedures used to backfill long-span structural plate structures shall be such that excessive structure distortion will not occur. Structure shape shall be checked regularly during backfilling to verify acceptability of the construction methods used. Magnitude of allowable shape changes will be specified by the Manufacturer (Fabricator of long-span structures). The Manufacturer shall provide a qualified shape-control Inspector to aid the Engineer during the placement of all structure backfill to the minimum cover level over the structure. The shape-control Inspector shall advise the Construction Engineer on the acceptability of all backfill material and methods and the proper monitoring of the shape. Structure backfill material shall be placed in horizontal uniform layers not exceeding a 200 mm loose lift thickness and shall be brought up uniformly on both sides of the structure. Each layer shall be compacted to a density not less than ninety percent (90%) modified density per AASHTO T180. The structure backfill shall be constructed to the minimum lines and grades shown in the contract documents, keeping it at or below the level of adjacent
soil or embankment. The following exceptions to the required structure backfill density shall be permitted:

- The area under the invert,
- The 300 mm to 450 mm width of soil immediately adjacent to the large radius side plates of high-profile arches and inverted-pear shapes, and
- The lower portion of the first horizontal lift of overfill carried ahead of and under the small, tracked vehicle initially crossing the structure.

3. Box Culverts

Structure backfill material shall be placed in uniform, horizontal layers not exceeding a 200 mm maximum loose lift thickness and compacted to a density not less than ninety percent (90%) modified density per AASHTO T 180. The structure backfill shall be constructed to the minimum lines and grades shown in the contract documents, keeping it at or below the level of the adjacent soil or embankment.

4. Concrete Backfill

The concrete backfill shall be placed in the trench against undisturbed material at the sides and bottom of the trench and in a manner that will prevent floating or shifting of the pipe, and voids in, or segregation of, the concrete. Foreign material which falls into the trench, prior to or during placing of the concrete, shall be immediately removed. Where necessary, earth plugs shall be constructed and compacted at the ends of the planned concrete backfill to contain the concrete within the trench.

The surface of the concrete backfill shall be broomed with a heavy broom to produce a uniform rough surface if asphalt concrete is to be placed directly thereon. No material shall be placed on top of the concrete backfill until 8 hours after placing the concrete backfill.

The level of lean concrete backfill around culverts shall be determined by the Engineer according to the nature of soil surrounding the culvert.

25.4.2.5. Bracing

When required, temporary bracing shall be installed and shall remain in place as long as necessary to protect workers and to maintain structure shape during erection.

For long-span structures which require temporary bracing or cabling to maintain the structure in shape, the supports shall not be removed until the structure backfill is placed to an elevation to provide the necessary support. In no case shall internal braces be left in place when backfilling reaches the top quadrant of the pipe or the top radius arc portion of a long-span structure.

25.4.2.6. Arch Substructures and Headwalls

Substructures and headwalls shall be designed in accordance with the applicable requirements of (MA-100-D-V1/2 & V2/2).

The ends of the corrugated metal arch shall rest in a keyway formed into continuous concrete footings, or shall rest on a metal bearing surface, usually an angle or channel shape, which is securely anchored to or embedded in the concrete footing.

When specified, the metal bearing may be a hot-rolled or cold-formed galvanized steel angle or channel. These shapes shall be not less than 5 mm in thickness and shall be securely anchored to the footing at a maximum spacing of 0.6 m. When the metal bearing member is not completely embedded in a keyway in the footing, one vertical
Construction Precautions  

Section 25: Steel Culverts  

Leg shall be punched to allow the end of the corrugated plates to be bolted to this leg of the bearing member.

Where an invert slab is provided which is not integral with the arch footing, the invert slab shall be continuously reinforced.

25.4.2.7. Inspection Requirements for Corrugated Metal Pipe

CMP shall be inspected after placement in the trench, and as required during backfilling to ensure that final installation conditions allow the pipe to perform as designed.

During the initial phase of the installation process, inspection shall concentrate on detecting improper practice and poor workmanship. Errors in line and grade, as well as any improper assembly or backfill techniques, shall be corrected prior to placing significant backfill or trench fill. Coupling bands shall be properly indexed with the corrugation and tightened, and bell/spigot joints shall be properly seated to prevent the infiltration of soil fines. Where gaskets are used, they shall not bulge or hang into the pipe and, if visible, should appear uniformly oriented around the pipe.

Racking or denting of the pipe shall be taken to indicate improper backfill placement, which shall be corrected. Wall sections damaged during installation shall be evaluated and then repaired or the section of the pipe shall be replaced.

Coated pipes shall be inspected to ensure the coating has no cracks, scratches, or locations of peeling. Coatings shall be repaired in accordance with material specification requirements.

Final internal inspections shall be conducted on all buried CMP installations to evaluate issues that may affect long-term performance. Final inspections shall be conducted no sooner than 30 days after completion of installation and final fill.

Shallow cover installations shall be checked to ensure the minimum cover level is provided.

The inspection will verify that bedding, backfill, and compaction requirements are followed during installation. The pipe shall be checked for alignment, joint separation, cracking at bolt holes, localized distortions, bulging, flattening, or racking. Minimum or near-minimum cover installations shall be inspected prior to and immediately after vehicular load is applied.

25.5. Construction Precautions

The structures covered by this section shall be investigated for all critical stages in their installation and in the final intended purpose. For construction loads, additional cover may be required beyond that required in the final condition to which the design loads apply. In the absence of more specific information, the cover depths in Table 25.3 may be considered for the smaller structures indicated. The minimum covers indicated should be increased when site conditions so indicate. The Engineer or the Manufacturer shall provide guidance for structure spans or axle loads not listed.
Table 25.3: Minimum Cover for Construction Loads on Circular, Pipe-Arch, Elliptic, and Underpass Shapes

<table>
<thead>
<tr>
<th>Pipe Span (m)</th>
<th>(80-222) kN</th>
<th>(222-333) kN</th>
<th>(333-490) kN</th>
<th>(490-667) kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.3-1)</td>
<td>0.6</td>
<td>0.75</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>(1.2-1.8)</td>
<td>0.9</td>
<td>0.9</td>
<td>1</td>
<td>1.2</td>
</tr>
<tr>
<td>(2-3)</td>
<td>0.9</td>
<td>1</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>(3.2-3.65)</td>
<td>1</td>
<td>1.2</td>
<td>1.4</td>
<td>1.4</td>
</tr>
</tbody>
</table>

The Contractor shall provide any additional cover required to avoid damage to the pipe. Minimum cover shall be measured from the top of the pipe to the top of the maintained construction roadway surface.

The surface shall be maintained to provide adequate cover until paving is completed, or until the project is accepted by the owner if paving is not required.

25.6. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6. "control and acceptance of materials and work", and this section requirements. For work acceptance, Contractor shall apply quality control for steel culverts work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.

25.6.1. Quality Control

All steel culverts work and materials should be controlled and inspected to insure that the work is according to the requirements of materials mentioned in the article 25.2, also, all shop drawing of the construction should be reviewed and insure that it has enough detailed information before starting the construction. All material used in construction should be checked and controlled according to the quality requirements mentioned in the section 25.3 and Table 25.6 for each elements of the work including the materials of the base and bedding.

For work acceptance the construction work procedure should be inspected to insure that is according to the collection and installation requirements mentioned in the section 25.4.1 and 25.4.2.

25.6.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of work, that are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that insure the quality of all works that was finished according to the requirements for this work.

25.7. Measurement and Payment

25.7.1. Measurement

Corrugated metal and structural plate pipe, pipe arches, arches, and box culverts shall be measured in linear meters installed in place, completed and accepted. The number of linear meters shall be the average of the top and bottom centerline lengths
for pipe, the bottom centerline length for pipe arches and box culverts, and the average of springline lengths for arches.

25.7.2. **Payment**

Separate pay items or provision for including excavation, backfill, and concrete for arches shall be provided for in the contract documents. The lengths as measured above shall be paid for at the contract prices per linear meter bid for corrugated metal and structural plate pipe, pipe-arch, arch, or box culvert of the sizes specified in the contract documents. Such price and payment shall constitute full compensation for furnishing, handling, erecting, inspecting shape control, and installing the pipe, pipe-arches, arches, or box culverts, and for all materials, labor, equipment, tools, and incidentals necessary to complete this item. Such price and payment shall also include the cost of excavation, bedding material, backfill, concrete headwalls, end walls, and foundations for pipe, pipe-arches, and box culverts. Separate payment will be made for excavation, backfill, concrete or masonry headwalls, and foundations for arches.

Payment will be made as indicated in Table 25.4. And the quality control requirements for steel culverts are shown in Table 25.5.

---

**Table 25.4: Metal Culverts Pay Items**

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.1</td>
<td>Metal Culverts</td>
<td>Linear Meter</td>
</tr>
</tbody>
</table>

**Table 25.5: Quality Control Requirements For Steel Culverts**

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation</td>
<td>The foundation under the pipe shall be investigated for its adequacy to support the loads</td>
<td>Field and laboratory inspections as CBR</td>
<td>In situ</td>
<td>As directed by the engineer</td>
<td>Article 25.4.2.2</td>
</tr>
<tr>
<td>Bedding</td>
<td>Depending on the shape of the pipe</td>
<td>Measurement</td>
<td>In situ</td>
<td>---------------------</td>
<td>Article 25.4.2.3</td>
</tr>
</tbody>
</table>
Table 25.6: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>As specified</td>
<td>AASHTO M 36</td>
<td>ASTM A 760/A 760M</td>
<td>Standard Specification for Corrugated Steel Pipe, Metallic-Coated for Sewers and Drains</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO M 218</td>
<td></td>
<td>Standard Specification for Steel Sheet, Zinc-Coated (Galvanized), for Corrugated Steel Pipe</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO M 196</td>
<td>ASTM B 745/B 745M</td>
<td>Standard Specification for Corrugated Aluminum Pipe for Sewers and Drains</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO M 274</td>
<td></td>
<td>Standard Specification for Steel Sheet, Aluminum-Coated (Type 2), for Corrugated Steel Pipe</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO M 219</td>
<td>ASTM B 746/B 746M</td>
<td>Standard Specification for Corrugated Aluminum Alloy Structural Plate for Field-Bolted Pipe, Pipe-Arches, and Arches</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO M 167MfM 167</td>
<td>ASTM A 761/A 761 M</td>
<td>Standard Specification for Corrugated Steel Structural Plate, Zinc-Coated, for Field-Bolted Pipe, Pipe-Arches, and Arches</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 307</td>
<td></td>
<td>Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO M 190</td>
<td></td>
<td>Standard Specification for Bituminous Coated Corrugated Metal Culvert Pipe and Pipe Arches</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO M 246</td>
<td>ASTM A 742/A 742M</td>
<td>Standard Specification for Steel Sheet, Metallic Coated and Polymer Precoated for Corrugated Steel Pipe</td>
</tr>
<tr>
<td>As specified</td>
<td>AASHTO M 145</td>
<td></td>
<td>Standard Specifications for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes</td>
</tr>
<tr>
<td>As specified</td>
<td>ASTM A 449</td>
<td></td>
<td>Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use</td>
</tr>
</tbody>
</table>
References

As specified | ASTM F 468 | Standard Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use
--- | --- | ---
As specified | AASHTO T99 | Standard Method of Test for the Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in)
As specified | AASHTO T180 | Standard Method of Test for Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop

25.8. References
AASHTO/AWS D1.5M/D1.5- "Bridge Welding Code"-2002.


AASHTO LRFD Construction Specifications Second Edition 2004. Sec (22)

CALIFORNIA:“California Department of Transportation -Construction Manual”- 2006- Sec. (66)

TEXAS:“Texas Department of Transportation - Standard Specifications for Construction and Maintenance of Highways, Streets, and Bridges”-2006- Sec. (460)

SECTION 26. CONCRETE CULVERTS

26.1. General

Culverts may be used for transverse drains under the Roadway or as conduits for water pipe or other utilities passing under the Roadway.

This work shall consist of fabricating, furnishing, and inspecting buried precast concrete culverts conforming to these Specifications, Section 10 of the (MA-100-D-V2/2), and the details shown in the contract documents. Precast reinforced concrete pipe shall be circular, arch, or elliptical, as specified in the contract documents. Precast reinforced concrete box sections shall be of the dimensions specified in the contract documents.

26.2. Definitions

*Oakum* Fibers taken from unraveled old ropes that when soaked in tar are used for caulking gaps.

26.3. Working Drawings

When complete details are not provided in the contract documents, or the standard details specifications, the Contractor shall submit working drawings and substantiating calculations of the proposed structure or installation system. Fabrication or installation of the structure shall not begin until the Engineer has approved the drawings. The working drawings shall show complete details and substantiating calculations of the structure, the materials, equipment, and installation methods proposed.

Working drawings shall be submitted in advance of the start of the work to allow for their review, revision, and approval without delay to the work. Approval by the Engineer shall not relieve the Contractor of any contractual responsibility.

26.4. Materials

26.4.1. Reinforced Concrete Culverts

The materials for reinforced concrete culverts shall meet the requirements of the classes and sizes specified in [Table 26.1].

<table>
<thead>
<tr>
<th>Type</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular Pipe</td>
<td>AASHTO M 170 (ASTM C 76) or AASHTO M 242 (ASTM C 655)</td>
</tr>
<tr>
<td>Arch Pipe</td>
<td>AASHTO M 206 (ASTM C 506)</td>
</tr>
<tr>
<td>Elliptical Pipe</td>
<td>AASHTO M 207 (ASTM C 507)</td>
</tr>
<tr>
<td>Box Sections</td>
<td>AASHTO M 259 and AASHTO M 273 or ASTM C 1433</td>
</tr>
</tbody>
</table>
26.4.2. Joint Sealants

26.4.2.1. General

The Contractor shall furnish to the Engineer a certificate of compliance stating that the material being furnished conforms to the joint property requirements.

The manufacturer's design and production tolerance for the annular space within the manufactured joint will determine the type of joint which will be required for sealing of the joints.

When the annular space within the pipe joints (algebraic difference in diameters measured between the exterior edges of the pipe at the spigot end and the interior faces of the hub at the shoulder of the joint) falls within the following ranges, the type sealer noted thereafter will be used.

<table>
<thead>
<tr>
<th>Total Annular Space</th>
<th>Type Sealer</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 mm or less</td>
<td>Bituminous Plastic Cement</td>
</tr>
<tr>
<td>6 mm to 13 mm</td>
<td>Mortar or Bituminous Plastic Cement As elected by the Contractor</td>
</tr>
<tr>
<td>13 mm or more</td>
<td>Mortar</td>
</tr>
</tbody>
</table>

26.4.2.2. Cement Mortar

Mortar shall be composed of one part portland cement and two parts sand by volume. Sand shall be well graded and of such size that all will pass sieve No.8 (2.36 mm).

The materials shall be mixed to a consistency suitable for the purpose intended and used within 30 min after the mixing water has been added. Admixtures, if any, shall be approved by the Engineer prior to use.

1. Placing Cement Mortar

The lower portion of the receiving end of the pipe shall be cleaned. Plaster the inside with sufficient joint mortar to bring the inner surfaces of the abutting pipe sections flush and even. Fit the sections as close as the construction of the culvert permits. Fill and seal joints with mortar inside and out. Clean excess mortar from the inside of the joint.

Mortar shall be cured outside of joints by covering with polyethylene sheeting or spraying with a curing compound. Backfill while mortar is plastic or, if mortar sets before backfilling, wait at least 24 hours before backfilling.

26.4.2.3. Bituminous Plastic Cement

Bituminous plastic cement meeting the Specifications noted in this Section, or other kinds of mastic joint sealer that has been approved by the Engineer, shall be used on joints whose design or manufacturing process produces an annular space within the limits noted in Table 26.2.

Bituminous joint sealing compound may be applied cold for sealing the joints of bell and spigot or tongue and groove storm or culvert pipe. Material furnished shall be
composed of a steam-refined petroleum asphalt dissolved in a suitable solvent and stiffened with a mineral filler.

1. Properties of Bituminous Plastic Cement

The Bituminous Plastic Cement shall be a smooth uniform mixture, not thickened or livered, and it shall show no separation which cannot be easily overcome by stirring. The material shall be of such consistency and properties that it can be readily applied with a trowel, putty knife, or caulking compound gun without pulling or drawing. When applied to the joint surfaces, it shall exhibit good adhesive and cohesive properties. The material shall meet the requirements specified in Table 26.3.

When applied in a layer 1.5 mm to 3 mm thick on a tinned metal panel and cured at room temperature for 24 hours, the bituminous plastic cement shall set to a rough, plastic coating, free from blisters.

<table>
<thead>
<tr>
<th>Table 26.3: Bituminous Plastic Cement Material Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Grease Cone Penetration</td>
</tr>
<tr>
<td>Unit Weight, kilograms per liter.</td>
</tr>
<tr>
<td>Non-Volatile</td>
</tr>
<tr>
<td>Ash, by ignition, by weights or masses</td>
</tr>
</tbody>
</table>

Test: Methods of tests shall be in accordance with the following:

- Crease Cone Penetration: AASHTO T 187
- Non-Volatile: ASTM D 2939
- Ash: ASTM D 128

26.4.2.4. Flexible Watertight Gaskets

Flexible watertight gasketed joints shall conform to the requirements of AASHTO M 198 (ASTM C 990 (ASTM C 990M)) or AASHTO M 315 (ASTM C 433) (AASHTO M 315M) (ASTM C 433M)) and shall be flexible and capable of withstanding expansion, contraction, and settlement of the pipeline.

All rubber gaskets shall be stored in as cool a place as practicable, preferably at 21°C or less.

Rubber gaskets, of the type requiring lubrication, shall be lubricated with the lubricant recommended and supplied by the Manufacturer of the pipe.

26.4.2.5. Other Joint Sealant Materials

Other joint sealant materials shall be submitted for testing in advance of their use and shall not be used prior to receiving approval from the Engineer.

In the following are some of other materials for joint:

1. Oakum and mortar.
2. Oakum and joint compound.
3. Coupling bands.
4. Preformed plastic sealing compound.
26.4.3. Bedding and Backfill Materials

The provisions of Article 26.5 "Construction" shall apply.

26.5. Construction

26.5.1. Assemble

Precast concrete units or elements shall be assembled in accordance with the Manufacturer's instructions. All units or elements shall be handled with reasonable care and shall not be rolled or dragged over gravel or rock. Care shall be taken to prevent the units from striking rock or other hard objects during placement.

26.5.2. Installation

26.5.2.1. General

Cracks in an installed precast concrete culvert that exceed 0.25 mm width shall be appraised by the Engineer considering the structural integrity, environmental conditions, and the design service life of the culvert. Cracks having greater widths or otherwise determined to be detrimental shall be sealed by a method approved by the Engineer.

For trench conditions, the trench shall be excavated to the dimensions and grade specified in the contract documents or ordered by the Engineer. The Contractor shall make such provisions as required to insure adequate drainage of the trench to protect the bedding during construction operations.

Proper preparation of foundation, placement of foundation material where required, and placement of bedding material shall precede the installation of the culvert. This work shall include necessary leveling of the native trench bottom or the top of foundation materials as well as placement and compaction of required bedding material to a uniform grade so that the entire length of pipe shall be supported on a uniformly slightly yield bedding. The backfill material shall be placed and compacted around the culvert in a manner to meet the requirements specified.

Materials used for foundation improvements, bedding, and structure backfill shall have gradations compatible with adjacent soils to avoid migration. Where material gradations cannot be properly controlled, adjacent materials shall be separated with a suitable geo-textile.

26.5.2.2. Joints

Joints for reinforced concrete pipe and precast reinforced concrete box sections shall comply with the details shown in the contract documents and on the approved working drawings. Each joint shall be sealed to prevent infiltration of soil fines or water as required by the contract documents. Field tests may be required by the Engineer whenever there is a question regarding compliance with contract requirements.

26.5.2.3. Foundation Bedding and Backfill

1. General

If rock strata or boulders are encountered under the culvert within the limits of the required bedding, the rock or boulders shall be removed and replaced with bedding
material. The foundation shall be comprised of stiff to hard in-situ soil, stabilized soil or compacted fill material. If the foundation is rock or other unyielding soil, then bedding shall be 150mm as a minimum. Where, in the opinion of the Engineer, the natural foundation soil is such as to require stabilization, such material shall be replaced by a layer of bedding material. Where an unstable and/or unsuitable material (e.g., peat or muck) is encountered at or below invert elevation during excavation, the necessary subsurface exploration and analysis shall be made and corrective treatment shall be as directed by the Engineer.

Where rock or other unyielding foundations exist and blasting is anticipated, the Engineer may require that suitable steps be taken to protect the pipe.

2. Precast Reinforced Concrete Circular, Arch and Elliptical Pipe

A bedding of a class, specified in the contract documents or on the working drawings, shall be provided. The type of installation specified shall conform to one of the types of installation given in Table 26.4 and Table 26.5 and the details shown in Figure 26.1 through Figure 26.4 which defines soil areas and critical dimensions for circular, arch, and elliptical pipes.

![Figure 26.1: Standard Embankment Installation Round Pipe.](image)

![Figure 26.2: Standard Trench Installation Round pipe](image)
Figure 26.3: Embankment Beddings – Miscellaneous Shapes
Figure 26.4: Trench Beddings – Miscellaneous Shapes
Table 26.4: Standard Embankment Installation Soils and Minimum Compaction Requirements

<table>
<thead>
<tr>
<th>Installation type</th>
<th>Bedding Thickness</th>
<th>Haunch and Outer Bedding</th>
<th>Lower side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>For soil foundation, $B_c/24$ minimum, not less than 0.08 m For rock foundation, use $B_c/12$ minimum, not less than 0.15 m</td>
<td>95% (A1, A3 or SW)</td>
<td>90% (A1, A3 or SW), 95% (A2, A4 or ML) or 100% (A5, A6 or CL)</td>
</tr>
<tr>
<td>Type 2-Installations are available for horizontal elliptical, vertical elliptical and arch pipe</td>
<td>For soil foundation, $B_c/24$ minimum, not less than 0.08 m For rock foundation, use $B_c/12$ minimum, not less than 0.15 m</td>
<td>90% (A1, A3 or SW) or 95% (A2, A4 or ML)</td>
<td>85% (A1, A3 or SW), 90% (A2, A4 or ML) or 95% (A5, A6 or CL)</td>
</tr>
<tr>
<td>Type 3-Installations are available for horizontal elliptical, vertical elliptical and arch pipe</td>
<td>For soil foundation, $B_c/24$ minimum, not less than 0.08 m For rock foundation, use $B_c/12$ minimum, not less than 0.15 m</td>
<td>85% (A1, A3 or SW), 90% (A2, A4 or ML) or 95% (A5, A6 or CL)</td>
<td>85% (A1, A3 or SW), 90% (A2, A4 or ML) or 95% (A5, A6 or CL)</td>
</tr>
<tr>
<td>Type 4</td>
<td>For soil foundation, no bedding required. For rock foundation, use $B_c/12$ minimum, not less than 0.15 m</td>
<td>No compaction required, except if (A5, A6 or CL), use 85% (A5, A6 or CL)</td>
<td>No compaction required, except if (A5, A6 or CL), use 85% (A5, A6 or CL)</td>
</tr>
</tbody>
</table>

The following interpretations apply to Table 26.4:

- Compaction and soil symbols, i.e., "95% (SW or (A1, A3))" shall be taken to refer to (SW or (A1, A3)) soil material with minimum standard proctor compaction of ninety-five percent (95%). Equivalent modified proctor values shall be as given in Table 26.6.
- Soil in the outer bedding, haunch and lower side zones, except within $B_c/3$ from the pipe spring line, shall be compacted to at least the same compaction as the majority of soil in the overfill zones.
- The minimum width of a subtrench for type 1 through type 3 installation shall be $B_c+0.6\text{ m}$ or $1.33\text{ B}_c$, whichever is greater or wider if required for adequate space to attain the specified compaction in the haunch and bedding zones.
- For sub trenches with walls of natural soil, any portion of the lower side zone in the subtrench wall shall be at least as firm as an equivalent soil placed to the compaction requirements specified for the lower side zone and as firm as the majority of soil in the overfill zone, or shall be removed and replaced with soil compacted to the specified level.

Only Type 2 and 3 installations are available for horizontal elliptical, vertical elliptical and arch pipe.

The required bedding thickness is the thickness of the bedding after placement of the pipe on the bedding and is prior to placement of the backfill.
Table 26.5: Standard Trench Installation Soils and Minimum Compaction Requirements

<table>
<thead>
<tr>
<th>Installation Type</th>
<th>Bedding Thickness</th>
<th>Haunch and Outer Bedding</th>
<th>Lower Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>For soil foundation, Bc/24 minimum, not less than 0.08 m For rock foundation, use Bc/12 minimum, not less than 0.15 m</td>
<td>95% (A1· A3 or SW)</td>
<td>90% (A1· A3 or SW), 95% (A2· A4 or ML) or 100% (A5· A6 or CL), or natural soils of equal firmness</td>
</tr>
<tr>
<td>Type 2</td>
<td>For soil foundation, Bc/24 minimum, not less than 0.08 m For rock foundation, use Bc/12 minimum, not less than 0.15 m</td>
<td>90% (A1· A3 or SW) or 95% (A2· A4 or ML)</td>
<td>85% (A1· A3 or SW), 90% (A2· A4 or ML), 95% (A5· A6 or CL), or natural soils of equal firmness</td>
</tr>
<tr>
<td>Type 3</td>
<td>For soil foundation, Bc/24 minimum, not less than 0.08 m For rock foundation, use Bc/12 minimum, not less than 0.15 m</td>
<td>85% (A1· A3 or SW), 90% (A2· A4 or ML) or 95% (A5· A6 or CL)</td>
<td>85% (A1· A3 or SW), 90% (A2· A4 or ML), or 95% (A5· A6 or CL), or natural soils of equal firmness</td>
</tr>
<tr>
<td>Type 4</td>
<td>For soil foundation, no bedding required. For rock foundation, use Bc/12 minimum, not less than 0.15 m.</td>
<td>No compaction required, except if (A5· A6 or CL), use 85% (A5· A6 or CL)</td>
<td>85% (A1· A3 or SW), 90% (A2· A4 or ML), 95% (A5· A6 or CL), or natural soils of equal firmness</td>
</tr>
</tbody>
</table>

The following interpretations apply to Table 26.5:

- Compaction and soil symbols, i.e., "95% (SW or (A1, A3))" shall be taken to refer to (SW or (A1, A3)) soil material with minimum standard proctor compaction of ninety-five percent (95%). Equivalent modified proctor values shall be as given in Table 26.6.
- The trench top elevation shall be no lower than 0.1H below finish grade, or for roadways, its top shall be no lower than an elevation of 300 mm below the bottom of the pavement base material.
- Soil in bedding and haunch zones shall be compacted to at least the same compaction as specified for the majority of soil in the backfill zone.
- The minimum trench width for Type 1 through Type 3 installation shall be Bc+0.6 m or 1.33 Bc, whichever is greater, or wider if required for adequate space to attain the specified compaction in the haunch and bedding zones.
- For trench walls that are within ten degrees of vertical, the compaction or firmness of the soil in the trench walls and lower side zone need not be considered.
• For trench walls with greater than ten-degree slopes that consist of embankment, the lower side shall be compacted to at least the same compaction as specified for the soil in the backfill zone.
• Only Type 2 and 3 installations are available for horizontal elliptical, vertical elliptical and arch pipe.
• The required bedding thickness is the thickness of the bedding after placement of the pipe on the bedding and is prior to placement of the backfill.
• The AASHTO M 145, ASTM D 2487 soil classifications equivalent to the generic soil types in the standard installations may be taken from Table 26.6.

<table>
<thead>
<tr>
<th>SIDD Soil</th>
<th>Representative Soil Types</th>
<th>Percent Compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>USCS</td>
<td>AASHTO</td>
</tr>
<tr>
<td>Gravelly Sand</td>
<td>SW, SP, GW, GP</td>
<td>A1,A3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sandy Silt</td>
<td>GM, SM, ML</td>
<td>A2,A4 or ML</td>
</tr>
<tr>
<td></td>
<td>Also GC, SC with than 20% passing a No. 200 sieve</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silty Clay</td>
<td>GL, MH, GC, SC</td>
<td>A5,A6 or CL</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH</td>
<td>Not allowed for haunch or bedding</td>
<td>A7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Standard Installation Direct Design Soil

3. Precast Reinforced Concrete Box Sections

Unless otherwise permitted herein, a bedding shall be provided for the type of installation specified conforming to Figure 26.5, unless in the opinion of the Engineer, the natural soil provides a suitable bedding.
Bedding material may be granular material, all of which passes a 9.5 mm sieve and not more than ten percent (10%) of which passes a sieve No. 200 (75 µm). Backfill shall be select material and shall be free of organic material, rock fragments larger than 75 mm in the greatest dimension, frozen lumps, and shall have moisture content within the units required for compaction.

**Figure 26.5: Bedding and Backfill Requirements**

### 26.5.2.4. Placing Culvert Sections

Unless otherwise authorized by the Engineer, the laying of culvert sections on the prepared bedding shall be started at the outlet and with the bell end pointing upstream and the spigot or tongue end pointing downstream and shall proceed toward the inlet end with the abutting sections properly matched, true to the established lines and grades. Where pipe with bells is installed, bell holes shall be excavated in the bedding to such dimensions that the entire length of the barrel of the pipe will be supported by the bedding when properly installed as shown in **Figure 26.6**. Proper facilities shall be provided for hoisting and lowering the sections of culvert into the trench without disturbing the prepared bedding and the sides of the trench. The ends of the section shall be carefully cleaned before the section is jointed. The section shall be fitted and matched so that when laid in the bed it shall form a smooth, uniform conduit. When elliptical pipe with circular reinforcing or circular pipe with elliptical reinforcing is used, the pipe shall be laid in the trench in such position that the markings "Top" or "Bottom," shall not be more than five degrees from the vertical plane through the longitudinal axis of the pipe. Adjustments in grade by exerting force on the culvert with excavating equipment or by lifting and dropping the culvert shall be prohibited. If the installed culvert section is not on grade after joining, the section shall be completely un-joined, the grade corrected and the section rejoined.

**Figure 26.6: Excavation of Bell Holes for Uniform Support**
Multiple installations of reinforced concrete culverts shall be laid with the center lines of individual barrels parallel at the spacing shown in the contract documents. Pipe and box sections used in parallel installations require positive lateral bearing between the sides of adjacent pipe or box sections. Compacted earth fill, granular backfill, or grouting between the units are considered means of providing positive bearing.

The joint ends, when using rubber gaskets, shall be protected from mud, silt, gravel, or other unwanted material. The pipe sections with gaskets attached shall be laid, removed, cleaned, re-lubricated, and gaskets disturbed or contaminated shall be reseated.

The joints shall be forced-home using the pipe manufacturer’s recommended procedure. Driving or ramming by hand or machinery shall not be done. The last section of each day's run shall be blocked to prevent creep.

A dike or plug of impervious material shall be placed near the intake end of the culvert to prevent piping. The dike shall be 0.6 m long and adequately surround the pipe to form an impervious barrier.

The ends of the pipe or pipe arch shall be rigidly supported to prevent movement before and during the construction of end walls or headers.

Culverts shall not be left extending beyond the staked limits unless approved by the Engineer.

26.5.2.5. Haunch, Lower Side, and Backfill or Overfill

1. Precast Reinforced Concrete Circular Arch and Elliptical Pipe
   Haunch material, low side material, and overfill material shall be installed to the limits shown on Figure 26.1 through Figure 26.4.

2. Precast Reinforced Concrete Box Sections
   Backfill material shall be installed to the limits shown in Figure 26.5 for the embankment or trench condition.

3. Placing of Haunch, Lower Side, and Backfill or Overfill
   Fill material shall be placed in layers with a maximum loose thickness of 200 mm and compacted to obtain the required density. The fill material shall be placed and compacted with care under the haunches of the culvert and shall be raised evenly and simultaneously on both sides of the culvert. For the lower haunch areas of Type 1, 2, and 3 Standard Installations, soils requiring ninety percent (90%) or greater standard proctor densities shall be placed in layers with a maximum thickness of 200 mm and compacted to obtain the required density. The width of trench shall be kept to the minimum required for installation of the culvert. Ponding or jetting will be only by the permission of the Engineer.

   Backfill shall be placed in horizontal layers. And shall not be placed against concrete less than seven days-old or until eighty percent (80%) of the design strength is achieved.

   Backfill for the most shapes of culverts is explicated in the following:

a. Pipe culverts
   Material shall be placed and compacted in evenly balanced layers on each side of each pipe culvert.
Backfill according to one of the following:

**a1. Pipe Culverts with Compacted Backfill**

Backfill material shall be placed and compacted to a height of 0.3 m above the top of the pipe. Complete the backfilling of the trench with suitable roadway excavation or unclassified borrow.

**a2. Pipe Culverts with Lean Concrete Backfill**

Pipe shall be placed and staked to prevent floating and movement.

Lean concrete backfill shall be mixed and placed by pug-mill, rotary drum, or other approved mixer to obtain a uniform mix.

Lean concrete backfill shall be placed in a uniform manner that prevents voids in, or segregation of the backfill.

When backfilling around culverts and other structures, lean concrete backfill shall be placed in a manner that does not float or shift the structure. The backfill shall be brought up evenly on all sides of the structure.

When lean concrete backfill is being placed at or below an atmospheric temperature of one degree Celsius (1°C), at least 4 hours shall elapse before backfilling over lean concrete backfill.

The level of the lean concrete backfill around culverts shall be determined by the Engineer according to the nature of soil in which the culverts will be placed.

**b. Arch Culverts with Headwalls**

Backfill according to one of the following:

**b1. Before Headwalls Placement**

The first backfill material shall be placed and compacted midway between the ends of the arch.

Backfill material shall be placed and compacted in layers on both sides of the arch to form as narrow a ramp as possible.

The ramp shall be built evenly on both sides until reaching the top of the arch.

The remainder of the backfill material shall be placed from the top of the ramp working both ways to the ends.

The backfill material shall be compacted evenly in layers on both sides of the arch.

**b2. After Headwalls Placement**

The first backfill material shall be placed and compacted adjacent to one headwall.

Backfill material shall be placed and compacted evenly in layers on both sides of the arch adjacent to the headwall until reaching the top of the arch.

Remainder of the backfill material shall be placed from the top of the arch working toward the other headwall.

The backfill material shall be compacted evenly in layers on both sides of the arch.

**4. Cover Over Culvert during Construction**

If the passage of construction equipment over an installed culvert is necessary during project construction, compacted overfill in the form of a ramp shall be constructed to a minimum elevation of 0.9 m over the top of the culvert or to a height
such that the equipment loads on the culvert do not exceed the culvert design strength. In an embankment installation, the overfill shall extend a minimum of one culvert diameter width or 0.9 m, whichever is greater, beyond each side of the culvert to prevent possible lateral displacement of the culvert. If a large volume of construction traffic must cross an installed culvert, the point of crossing shall be changed occasionally to minimize the possibility of lateral displacement.

26.6. Field Inspection

26.6.1. General

Internal inspections shall be conducted on all buried rigid pipe installations to evaluate issues that may affect long-term performance such as cracks, joint quality, and alignment. Inspections shall be conducted no sooner than 30 days after completion of installation and final fill.

26.6.2. Misalignment

Misalignment may be taken to indicate the presence of problems in the supporting soil or contractor grade-control. The vertical and horizontal alignment of the culvert barrel shall be checked by sighting along the crown, invert, and sides of the culvert, and by checking for differential movement or settlement at joints between pipe sections. Vertical alignment shall be checked for sagging, faulting, and invert heaving. The inspector shall take into account pipes laid with camber or a grade change. Horizontal alignment shall be checked for straightness or smooth curvature.

26.6.3. Joint Defects

Leaking joints may be detected during low flows by visual observation of the joints, by checking around the ends of the culvert for evidence of piping, and if required in the contract, by special testing methods typically employed for sanitary sewers.

Differential movement, cracks, spalling, improper gasket placement, movement or settlement of pipe sections and leakage shall be noted in the inspection report. Severe joint cracks are similar in significance to separated joints.

Joint separations greater than pipe manufacturer's maximum limit shall be considered significant because they accelerate damage caused by exfiltration and infiltration resulting in the erosion of the backfill material.

Evidence of any soil migration through the Joint warrants further investigation to determine the source and if repair or replacement is required.

26.6.4. Longitudinal Cracks

Hairline longitudinal cracks in the crown or invert indicate that the steel has accepted part of the load. Cracks equal to or less than 0.25 mm in width are considered minor and only need to be noted in the inspection report.

Other signs of distress, such as differential movement, efflorescence, spalling, or rust stains shall also be noted. When cracks are wider than 0.25 mm, measurements shall be taken of the width, length, and locations of the cracks and diameter of the pipe, both horizontally and vertically. An evaluation shall be conducted by the Contractor and shall be submitted to the Engineer for review and approval considering the structural integrity, environmental conditions, and the design service life of the culvert.
Cracks having widths equal to or greater than 0.25 mm and determined to be detrimental shall be sealed by a method approved by the Engineer. Pipes with cracks having widths greater than 2.5 mm and determined by the Engineer to be beyond satisfactory structural repair shall be re-mediated or replaced. Pipes having displacement across the crack shall be repaired or replaced.

Inspection records for pipes with crack widths exceeding 0.25 mm shall be kept on file for monitoring conditions during subsequent inspections. Crack measurements and photographs shall be taken for monitoring conditions during subsequent inspections.

26.6.5. Transverse Cracks
Where transverse cracks are observed, they shall be monitored as described in Article 26.6.4 “Longitudinal Cracks”.

26.6.6. Spalls
Spalling may be detected by visual examination of the concrete along the edges of cracks. Tapping with a hammer shall be performed along the cracks to check for areas that have fractured but are not visibly separated. Such areas will produce a hollow sound when tapped. These areas may be referred to as de-laminations or incipient spalls. Pipe experiencing this type of problem shall be repaired or replaced.

26.6.7. Slabbing
Any pipe experiencing slabbing shall be repaired or replaced.

26.6.8. End Section Drop-Off
End drop-offs are caused by erosion of the material supporting the pipe sections on the outlet end of the culvert barrel. The end section shall be reset.

26.6.9. Follow Up
If any repairs or remedial action is performed on the pipe, a follow-up inspection following the same guidelines as outlined in Article 26.6, “Field Inspection” shall be performed between one and two years’ time.

26.7. Surface Finish
Defects that indicate proportioning, mixing, and molding not in compliance with the specification, or surface defects indicating honeycombed or open texture that would adversely affect the function of the pipe, shall be repaired or the pipe replaced.

26.8. Removing and Replacing Culverts
Where shown in the Plans or where designated by the Engineer, existing culverts shall be removed and re-laid in accordance with these Specifications. Any culvert damaged by the Contractor’s operations shall be replaced at the Contractor’s expense. In the case of concrete pipe, all joints of the pipe before being re-laid shall be cleaned so as to be free from all adhering material, including old mortar placed as a collar or seal in the original construction.

All culvert sections removed and not re-laid shall become the property of the Contractor.
26.9. Works Acceptance

All materials and works should be controlled according to the requirements of the article 3.6, "control and acceptance of materials and work", and this section requirements. For work acceptance, Contractor shall apply quality control for concrete culverts work through carrying out all the required procedures to insure that used materials, completion methods and completed works fulfill quality requirements stipulated in these general specifications and other contract documents.

26.9.1. Quality Control

All concrete culverts work and materials should be controlled and inspected to insure that the work is according to the requirements of materials mentioned in the article 26.3, also, all shop drawing of the construction should be reviewed and insure that it has enough detailed information before starting the construction. All material used in construction should be checked and controlled according to the quality requirements mentioned in the article 26.4 and Table 26.9 for each elements of the work including the materials of the base, bedding, embankments and seal materials.

For work acceptance the construction work procedure should be inspected to insure that is according to the collection and installation requirements mentioned in the article 26.5.1 and 26.5.2. Site inspection should be performed to insure that the work is clean and there are no damages, distresses, longitudinal and transverse cracks, joints distresses, and settlements in the cross-section, according to the article 26.6. Also, finishing the surfaces should be inspected to insure that it is conforming the requirements of section 26.7.

26.9.2. Quality Assurance

Ministry, at any time, has the right to insure the quality of work, that are conforming the required specification through carrying out or ordering others to carry out under its supervision the tests that insure the quality of all works that was finished according to the requirements for this work.

26.10. Measurement and Payment

26.10.1. Measurement

Culverts shall be measured in linear meters installed in place, completed and accepted. The number of meters shall be the average of the top and bottom centerline lengths for pipe and box sections.

26.10.2. Payment

The length determined as herein given shall be paid for at the contract unit prices per linear meter bid for culverts of the several sizes and shapes, as the case may be, which prices and payments shall constitute full compensation for furnishing, handling, and installing the culvert and for all materials, labor, equipment, tools, and incidentals necessary to complete this item. Such price and payment shall also include bedding material, backfill, reinforced concrete headwalls and end walls, and any required foundations.

Payment will be made as indicated in Table 26.7. And the quality control requirements for concrete culverts are shown in Table 26.8.
Table 26.7: Concrete Culverts Pay Items

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.1</td>
<td>Concrete Culverts</td>
<td>Linear Meter</td>
</tr>
</tbody>
</table>

Table 26.8: Quality Control Requirements For Concrete Culverts

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misalignment</td>
<td>Adjustment all vertical and horizontal alignment of the culvert and differential movement or settlement</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>---------</td>
<td>Article 26.6.2</td>
</tr>
<tr>
<td>Joint Defects</td>
<td>Leaking joints</td>
<td>Visual observation</td>
<td>In situ</td>
<td>---------</td>
<td>Article 26.6.3</td>
</tr>
<tr>
<td>Longitudinal Cracks and Transverse Cracks</td>
<td>Crack less or wider than 0.25 mm?</td>
<td>Surveying and measurement</td>
<td>In situ</td>
<td>each</td>
<td>Article 26.6.4, 26.6.5</td>
</tr>
<tr>
<td>Spalls</td>
<td>Areas that have fractured but are not visibly separated</td>
<td>Visual examination and tapping with a hammer</td>
<td>In situ</td>
<td>each</td>
<td>Article 26.6.6</td>
</tr>
<tr>
<td>Slabbing</td>
<td>Pipe which cut a log into slabs</td>
<td>Visual examination</td>
<td>In situ</td>
<td></td>
<td>Article 26.6.7</td>
</tr>
<tr>
<td>End Section Drop-off</td>
<td>Witch are caused by erosion of the material supporting the pipe sections on the outlet end of the culvert barrel</td>
<td>Visual examination and measurement</td>
<td>In situ</td>
<td>Each</td>
<td>Article 26.6.8</td>
</tr>
</tbody>
</table>
Table 26.9: AASHTO and ASTM Designation and its Title

<table>
<thead>
<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>as specified</td>
<td>AASHTO M 170</td>
<td>ASTM C 76</td>
<td>Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 242</td>
<td>ASTM C 655</td>
<td>Standard Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 206</td>
<td>ASTM C 506</td>
<td>Standard Specification for Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 207</td>
<td>ASTM C 507</td>
<td>Standard Specification for Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 198</td>
<td>ASTM C 990</td>
<td>Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 315</td>
<td>ASTM C 433</td>
<td>Specification for Quicklime and Hydrated Lime for Hypechlorite Bleach Manufacture</td>
</tr>
<tr>
<td>as specified</td>
<td>AASHTO M 273</td>
<td>ASTM C 1433</td>
<td>Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers</td>
</tr>
</tbody>
</table>

26.11. References
AASHTO LRFD Construction Specifications Second Edition 2004. Sec. 27

FHWA “FHWA “Standard Specifications For Construction Of Roads And Bridges On Federal Highway Projects Fp-03-Metric Units. Sec. 602

ALABAMA: “Alabama Department of Transportation Standard Specifications for Highway Construction”-2004- Sec. 846

Washington Standard Specifications for Road, Bridge, and Municipal Construction 2008 M 41-10 Sec. 7-02

ALASKA:“Alaska Department of Transportation And Public Facilities- Standard Specifications For Highway Construction- 2004 ” Sec. 603

SECTION 27. WEARING SURFACES

27.1. Description

This work shall consist of placing a wearing surface of durable and impervious material on the roadway surface of bridge decks, including the preparation of the surfaces of either existing or new decks to receive such an overlay of surfacing material.

The type and thickness of the wearing surface shall be as designated in the contract documents.

The materials and installation requirements for wearing surfaces of types other than latex-modified concrete shall be as specified in the contract documents.

Wearing surfaces that act compositely with the steel deck plate reduce deformations and stresses in the decks. The effectiveness of the wearing surface depends on its thickness, temperature-dependent elastic modulus, and bond characteristics.

Flexural stresses in the wearing surface may be reduced by limiting local deck flexibility, and by reducing the thickness of the wearing surface.

Selection of a wearing surface should include evaluation of the following requirements:

- Sufficient ductility and strength to accommodate expansion, contraction, and imposed deformation without cracking or debonding.
- Sufficient fatigue strength to withstand flexural stresses due to composite action of the wearing surface with the deck plate resulting from local flexure.
- Sufficient durability to resist rutting, shoving, and wearing;
- Imperviousness to water, motor vehicle fuels, and oils.
- Resistance to deterioration from solar radiation and aging, and de-icing salts.
- Provision of skid-resistant surface; and ability to distribute wheel loads.

Wearing surfaces are generally asphaltic concretes or latex-modified concrete. An asphaltic concrete overlay should not be used directly on a Portland cement concrete deck without a waterproofing membrane. All AC (asphalt cements) mixtures are inherently porous and readily conduct water and chlorides to the Portland cement concrete deck where they cannot be flushed off. Such impounded brine greatly accelerates bridge deck deterioration which is then difficult to observe or measure below the asphalt. The permeability of asphaltic concrete greatly increases with age. The design of such surfaces is well covered in Article 8.5.3, “General Specification of Urban Road Construction, First Edition 1426 H”.

Latex-modified concrete wearing surfaces shall be furnished and installed in accordance with these Specifications.

27.2. General

All equipment used to prepare the surface and to proportion, mix, place, and finish the latex concrete shall be subject to approval by the Engineer prior to use. This approval will be contingent on satisfactory performance and will be rescinded in the
event such performance is not being achieved. Equipment shall be on hand sufficiently ahead of the start of construction operations to be examined and approved. Any equipment leaking oil or any other containment onto the deck shall be immediately removed from the job site until repaired.

A technician who is well experienced in the proportioning, mixing, placing, and finishing of latex-modified concrete shall be employed by the Contractor and shall be present and in technical control of the work whenever these operations are underway. The qualifications of this technician, including a list of projects on which the technician was employed and the technician's level of responsibility on each, shall be submitted to and approved by the Engineer prior to the start of these operations.

Approval by the Engineer of equipment or technicians shall not relieve the Contractor of any responsibility for the successful completion of the work.

If not otherwise specified in the contract documents, the minimum thickness of latex-modified concrete wearing surfaces shall be 32 mm.

27.3. Materials

27.3.1. Portland Cement

Portland Cement shall conform to the requirement of Article 10.4.1, "Cements", except that only Types I or II shall be used.

27.3.2. Aggregate

Aggregate shall conform to the requirements of AASHTO M6 for fine aggregate and to AASHTO M 80 for coarse aggregate. Coarse aggregate shall be graded 13 mm to 4.75 mm per AASHTO M 43 (ASTM D 448).

27.3.3. Water

Water for mixing concrete shall conform to the requirements of Article 10.4.4, "Water".

27.3.4. Latex Emulsion

Formulated latex emulsion admixture shall be a non-hazardous, film forming, polymeric emulsion in water, to which all stabilizers have been added at the point of manufacture, and shall be homogeneous and uniform in composition.

Physical Properties-The latex modifier shall conform to the following requirements:

- Polymer Type Stabilizers Styrene Butadiene
- Nonionic Surfactants
- Portland Cement Composition Polydimethyl Siloxane
- Percent Solids 46.0 - 49.0
- Mass per liter at 25°C 1.0 kg
- Color White

A Certificate of Compliance signed by the Manufacturer of the latex emulsion, certifying that the material conforms to the above Specifications, shall be furnished for each shipment used in the work.

Latex admixture to be stored shall be kept in suitable enclosures that will protect it from freezing and from prolonged exposure to temperatures in excess of thirty degree
Celsius (30°C). Containers of latex admixture may be stored at the bridge site for a period not to exceed ten days. Such stored containers shall be covered completely with suitable insulating blanket material to avoid excessive temperatures.

27.4. Mix Design Of Latex-Modified Concrete (Lmc)

The latex-modified concrete for use on the project shall be a workable mixture and meet the following requirements specified in Table 27.1 and the following:

- Following sampling of the discharged, normally mixed material, the commencement of the slump test shall be delayed from 4 to 5 min.
- Water may be added to obtain slump within the prescribed limits.
- The dry weight ratios are approximate and should produce good workability but, due to gradation changes, may be adjusted within limits by the Engineer. The parts by weight of sand may be increased by as much as 0.2 if the coarse aggregate is reduced by an equivalent volume.

Table 27.1: Approximate Latex-Modified Concrete Mixture Proportions

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Amount for a volume of 1 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>299 kg</td>
</tr>
<tr>
<td>Sand</td>
<td>776 kg</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>517 kg</td>
</tr>
<tr>
<td>Latex*</td>
<td>92.7 Liter</td>
</tr>
<tr>
<td>Water</td>
<td>71.9 Liter</td>
</tr>
</tbody>
</table>

*Assumed 48% solids, 52% water by mass.

Because of the surfactants used in the manufacture of latex, excessive amounts of air can be entrained when latex is mixed into a portland-cement system, unless an antifoam agent is incorporated in the latex.

For styrene-butadiene latexes, these are usually silicone products and are often added by the latex supplier. The relationship between air content and antifoam agent content is a function of the specific latex, in particular, the level and type of its surfactant system and antifoam agent used. Field experience has shown that the composition of the cement and the aggregates can affect air content, so it is important to evaluate the mixture before use. No reported work has been done to identify the components of the cement or aggregates that affect the air content.

Unlike in conventional concrete, the addition of an air-entraining agent is not required in polymer modified concrete (PMC) for resistance to freezing and thawing. The latex provides this protection as some air is entrained by the latex and water during the mixing process. ACI 548.4 has a maximum air content of about 6.5%, but not a minimum. LMC does not have the air-void system necessary to pass ASTM C 666; however, more than 30 years of experience has shown that resistance to freezing and thawing is not a problem with LMC for reasons discussed previously.
27.5. Application

27.5.1. Surface Preparation

27.5.1.1. New Decks

The surfaces of new decks upon which a wearing surface overlay is to be placed shall be finished to a rough texture by coarse brooming or other approved methods.

After curing of the deck concrete is complete and before placing the overlay, the entire area of the deck surface and the vertical faces of curbs, concrete parapets, barrier walls, etc., up to a height of 25 mm above the top elevation of the overlay shall be blast-cleaned to a bright, clean appearance that is free from laitance, curing compound, dust, dirt, oil, grease, bituminous material, paint, and all foreign matter. The blast cleaning of an area of the deck shall normally be performed within the 24 hours period preceding placement of the overlay on the area. The blast cleaning may be performed by either wet sandblasting, high-pressure water blasting, blasting grits, shrouded dry sandblasting with dust collectors, or another method approved by the Engineer. Water blasting equipment shall operate with a minimum pressure of 24.5 MPa. The method used shall be performed so as to conform to applicable air and water pollution regulations and to applicable safety and health regulations. All debris, including dirty water, resulting from the blast cleaning operations shall be immediately and thoroughly cleaned from the blast-cleaned surfaces and from other areas where debris may have accumulated. The blast-cleaned areas shall be protected as necessary against contamination prior to placement of the overlay. Contaminated areas and areas exposed more than 36 hours after cleaning shall be blast-cleaned again as directed by the Engineer and at the Contractor's expense.

Just prior to placement of the overlay, all dust and other debris shall be removed by flushing with water or blowing with compressed air. The prepared surface shall then be soaked with clean water for not less than one hour prior to the placement of the latex overlay. Before the overlay is applied, all free water shall be blown out and off, and this procedure shall continue until the surface appears dry or barely damp.

The air supply system for blast cleaning and blowing shall be equipped with an oil trap in the air line, and provisions shall be made to prevent oil or grease contamination of the surface by any equipment prior to placement of the overlay.

27.5.1.2. Existing Decks

The surface of existing decks that have become contaminated by traffic usage or by deicing salts shall be scarified to the depth specified in the contract documents. If no depth is shown or specified, a minimum of 6 mm of material shall be removed by scarification.

Prior to beginning scarification and until operations are completed, all deck drains, expansion joints, and other openings where the Engineer determines that damage could result shall be temporarily covered or plugged to prevent entry of debris.

Scarifying shall be done with power operated mechanical scarifiers, or other approved devices, capable of uniformly removing the existing surface to the depths required without damaging the underlying concrete. Machine scarifiers shall not be operated so as to damage hardware such as drain grates and expansion joint armor. In areas where machine scarifying cannot reach and in areas of spalling and where steel reinforcement is exposed, scarifying and the removal of deteriorated or unsound
concrete shall be accomplished with hand tools. Pneumatic hammers heavier than nominal 200 N shall not be used.

No scarifying or chipping will be allowed within 1.8 m of a new overlay until 48 hours after its placement.

In areas where the Engineer determines that deteriorated or unsound concrete has been encountered, the concrete shall be removed to a depth of 20 mm below the top mat of reinforcing steel. A minimum of 20 mm clearance shall be required around the reinforcing steel, except where lower bar mats make this impractical. Care shall be exercised to prevent damaging the exposed reinforcing steel. All reinforcing steel shall be blast-cleaned. The repair areas are to be filled during the overlay operation.

After scarification and removal of unsound concrete has been completed, the deck surface shall be blast-cleaned and prepared as specified in Article 27.5.1.1, "New Decks".

27.5.2. Proportioning and Mixing

The Contractor shall submit to the Engineer for approval, 14 days prior to date of placement, the proposed mix design in writing and samples of all mix materials in sufficient quantity to produce a minimum of 0.08 m\(^3\) of concrete for laboratory mix design testing.

Proportioning and mixing equipment shall be a self-contained, mobile, continuous-mixing, volumetric proportioning-type mixer.

Continuous-type mixers shall be equipped so that the proportions of the cement, natural sand, and coarse aggregate can be fixed by calibration of the mixer and cannot be changed without destroying a seal or other indicating device affixed to the mixer. In addition to being equipped with a flow meter for calibrating the water supply portion of the mixer, the mixer shall also be equipped with a cumulative-type water meter that can be read to the nearest 0.4 Liter. The water meters shall be readily accessible, accurate to within one percent, and easy to read. Both water meters shall be subject to checking by the Engineer each time the mixer is calibrated. Approved methods for adding the admixture shall be provided. The admixtures shall be added so as to be kept separated as far as is practicable. The continuous-type mixer shall be calibrated to the satisfaction of the Engineer prior to starting the work. Yield checks normally will be made for each 38 m\(^3\) of mix. Recalibration will be necessary when indicated by the yield checks and at any other times the Engineer deems necessary to ensure proper proportioning of the ingredients. Continuous-type mixers that entrap unacceptable volumes of air in the mixture shall not be used.

The mixer shall be kept clean and free of partially dried or hardened materials at all times. It shall consistently produce a uniform, thoroughly blended mixture within the specified air content and slump limits. Malfunctioning mixers shall be immediately repaired or replaced with acceptable units.

Aggregate stockpiles being used should be of uniform moisture content. Mixing capability shall be such that finishing operations can proceed at a steady pace, with final finishing completed before the formation of the plastic surface film.
27.5.3. Installation

27.5.3.1. General

A detailed work plan including equipment and manpower shall be provided for approval before beginning any work.

Concrete batches shall not be carted over the completed overlay until the overlay concrete has attained a compressive strength of 21 MPa. If carts are used, provide timber planking of at least 20 mm thickness for the remainder of the curing period. Provide carts equipped with pneumatic tires. Curing operations shall not be interrupted for the purpose of carting concrete over finished slabs.

27.5.3.2. Weather Restrictions

The placement of latex-modified concrete shall not be started when the temperature is or is expected to fall below seven degree Celsius (7°C) or rise above twenty-seven degree Celsius (27°C), or when high winds, rain, or low humidity conditions are expected prior to final set of the concrete. If any of these conditions occur during placement, the placement shall be terminated and a straight construction joint formed. Placement at night may be necessary when daytime conditions are not favorable. If placement is performed at night, adequate lighting shall be provided by the Contractor.

27.5.3.3. Equipment

Placing and finishing equipment shall include hand tools for placing and brushing in freshly mixed latex-modified concrete and for distributing it to approximately the correct level for striking off with the screed. Hand-operated vibrators, screeds, and floats shall be used for consolidating and finishing small areas.

An approved finishing machine complying with the following requirements shall be used for finishing all large areas of work:

- The finishing machine shall be self-propelled and capable of forward and reverse movement under positive control. The length of the screed shall be sufficient to extend at least 150 mm beyond the edge of both ends of the section being placed. The finishing machine shall also be capable of consolidating the concrete by vibration and of raising all screeds to clear the concrete for traveling in reverse. The machine shall be either a rotating roller-type or an oscillating screed-type.
- Rotating roller-type machines shall have one or more rollers, augers, and 25 to 40 Hz vibratory pans.
- Oscillating screed-type machines shall have vibrators on the screeds whose frequency of vibration can be varied between 50 and 250 Hz. The bottom face of the screeds shall be not less than 100 mm wide and shall be metal.

Rails shall be required for the finishing machine to travel on. Rails shall be sufficiently rigid to support the weight of the machine without appreciable deflection and shall be placed outside of the overlay area. Rail anchorages shall provide horizontal and vertical stability and shall not be ballistically shot into concrete that will not be overlaid.

A suitable portable lightweight or wheeled work bridge shall be furnished for use behind the finishing operation.
27.5.3.4. Placing and Finishing

1. Placing

The finishing machine shall be test-run over the entire area to be overlayed each day before placement is started to ensure that the required overlay thickness will be achieved.

Immediately ahead of placing the overlay mixture, a thin coating of the polymer-modified concrete mixture to be used for the overlay shall be thoroughly brushed and scrubbed onto the surface as a grout-bond coat for the overlay. More coarse particles of the mixture which cannot be scrubbed into contact with the surface shall be removed and disposed of in a manner approved by the Engineer. Care shall be taken to ensure that all vertical as well as horizontal surfaces receive a thorough, even coating and that the rate of progress is limited so that the material brushed on does not become dry before it is covered with the full depth of latex-modified concrete.

The latex-modified concrete shall be placed on the prepared and grout-coated surface immediately after being mixed. The mixture shall be placed and struck off approximately 6 mm above final grade, then consolidated by vibration and finished to final grade with the approved finishing machine. Spud vibrators may be used in deep pockets, along edges, and adjacent to joint bulkheads. Supplemental vibration shall be provided along the meet lines where adjacent pours come together and along curb lines. Hand finishing with a float may be required along the edge of the pour or on small areas of repair.

Screed rails and construction bulkheads shall be separated from the newly placed material by passing a pointing trowel along their inside face. Expansion dams shall not be separated from the overlay. Care shall be exercised to ensure that this trowel cut is made for the entire depth and length of rails after the mixture has stiffened sufficiently.

2. Finishing

The finishing equipment shall be operated so as to produce a uniform, smooth, and even-textured surface. The final surface shall not vary more than 3 mm from a 3 m straightedge placed longitudinally thereon. Before the plastic film forms, the surface shall be textured by tinning in accordance with the requirements of Article 10.12.2.3, "Texturing".

3. Construction Joints

Planned construction joints shall be formed by bulkheads set to grade. Before placing concrete against previously placed overlay material, the construction joint shall be sawed to a straight vertical edge. Sawing of joints may be omitted if the bulkhead produces a straight, smooth, vertical surface. The face of the joint shall be sand or water blasted to remove loose material.

Longitudinal construction joints will be permitted only at the centerline of roadway or at lane lines unless otherwise shown in the contract documents or permitted by the Engineer.

In case of delay in the placement operation exceeding 1 hour in duration, an approved construction joint shall be formed by removing all material not up to finish grade and sawing the edge in a straight line. During minor delays of 1 hour or less, the end of the placement may be protected from drying with several layers of clean, wet burlap.
27.6. Curing

The surface shall be promptly covered with a single layer of clean, wet burlap as soon as the surface will support it without deformation.

Within 1 hour of covering with wet burlap, the burlap shall be rewet if necessary and a layer of 100 µm polyethylene film, or wet burlap-polyethylene sheets, shall be placed on the wet burlap, and the surface cured for 24 hours.

During cold weather, freshly placed LMC shall be protected from temperatures below seven degrees Celsius (7°C) during the first 72 hours of curing. If the temperature falls below seven degrees Celsius (7°C) during curing, the duration of the wet cure shall be extended as directed by the Engineer.

The overlay shall be protected from freezing during the cure period.

Traffic will not be permitted on the overlay while it is curing.

27.7. Testing and Acceptance

After curing is completed, the overlay will be visually inspected for cracking or other damage, and inspected for de-laminations and bond failures by the use of a chain drag or other suitable device.

Surface cracks not exceeding 10 mm in depth shall be sealed with an epoxy-penetrating sealer followed by an application of approved sand.

Any cracks exceeding 10 mm in depth shall be repaired by methods approved by the Engineer or the affected portions of the wearing surface shall be removed and replaced. Any delaminated or unbonded portions of the wearing surface or portions damaged by rain or freezing shall be removed and replaced.

After completion of the wet cure, the surface shall be tested for flatness and corrected, if necessary, as provided in Article 10.12.2.4, "Surface Testing and Correction".

All corrective work shall be at the Contractor's expense.

27.7.1. Compression Strength Test

Compression strength test shall be done according to ASTM C 31. Specimens shall be cured at the job site under the same conditions as the overlay. Specimens shall be tested to determine when overlay has achieved a specified strength of 21 MPa or as specified in the contract documents for opening to traffic.

27.8. Measurement and Payment

27.8.1. Measurement

Wearing surfaces and areas requiring scarification will be measured by the square meter based on dimensions of the completed work.

27.8.2. Payment

Wearing surfaces will be paid for at the contract price per square meter. Except as otherwise provided, the payment per square meter for wearing surfaces shall be considered to be full compensation for the cost of furnishing all labor, materials, equipment, incidentals, and for doing all work involved in preparing the surface and constructing the wearing surface as shown in the contract documents.
When a separate item is included in the contract documents for scarifying bridge decks, scarifying shall be paid for by the contract price per square meter. Such payment shall be considered to be full compensation for all costs involved with the scarifying work, including removal and disposal of debris.

The removal of unsound concrete which is encountered below the depth specified for scarifying shall be paid for as extra work.

Payment will be made as indicated in Table 27.2. And the quality control requirements for wearing surfaces are shown in Table 27.3.

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Pay Units</th>
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<tr>
<td>27.1</td>
<td>Wearing Surface</td>
<td>Square Meter</td>
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### Table 27.3: Quality Control Requirements For Wearing Surfaces

<table>
<thead>
<tr>
<th>Work</th>
<th>Descriptions</th>
<th>Test Method</th>
<th>Location of Sample</th>
<th>Frequency of Sampling</th>
<th>Requirements</th>
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<tbody>
<tr>
<td>Surface Preparation</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>New Decks</td>
<td>Surface shall be finished to a rough texture</td>
<td>Visual inspection</td>
<td>In situ</td>
<td></td>
<td>27.5.1.1</td>
</tr>
<tr>
<td>Existing Decks</td>
<td>A minimum of 6 mm of material shall be removed by scarification</td>
<td>Visual inspection</td>
<td>In situ</td>
<td></td>
<td>27.5.1.2</td>
</tr>
<tr>
<td>Proportioning and Mixing</td>
<td>Submitted Samples</td>
<td>Laboratory</td>
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<td></td>
<td>27.5.2</td>
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<tr>
<td></td>
<td>14 days prior to date of placement</td>
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<td></td>
<td></td>
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<tr>
<td>Placing</td>
<td>LMC shall be placed on the prepared and grout-coated surface</td>
<td>Visual inspection</td>
<td>------</td>
<td>------</td>
<td>27.5.3.4.1</td>
</tr>
<tr>
<td>Finishing</td>
<td>Result surface shall be a uniform, smooth, and even-textured</td>
<td>Surveying and visual inspection</td>
<td>------</td>
<td>------</td>
<td>27.5.3.4.2</td>
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Table 27.4: AASHTO and ASTM Designation and it’s Title

<table>
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<tr>
<th>ACCEPTANCE LIMIT</th>
<th>AASHTO DESIGNATION</th>
<th>ASTM DESIGNATION</th>
<th>TITLE</th>
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</thead>
<tbody>
<tr>
<td>as specified</td>
<td>AASHTO M6</td>
<td></td>
<td>Fine Aggregate for Portland Cement Concrete</td>
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<tr>
<td>as specified</td>
<td>AASHTO M 80</td>
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<td>Coarse Aggregate for Portland Cement Concrete</td>
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<td>as specified</td>
<td>AASHTO M 43</td>
<td>ASTM D 448</td>
<td>Standard Classification for Sizes of Aggregate for Road and Bridge Construction</td>
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<td>as specified</td>
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<td>ASTM C 31</td>
<td>Standard Practice for Making and Curing Concrete Test Specimens in the Field</td>
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<tr>
<td>as specified</td>
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<td>ASTM C 666</td>
<td>Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing</td>
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</tbody>
</table>

27.9. References

AASHTO LRFD Construction Specifications Second Edition 2004- Sec. 28

Texas (Item 439) “Texas Department of Transportation - Standard Specifications for Construction and Maintenance Of Highways, Streets, and Bridges”

Canadian Highway Bridge Design Code -2006-(C10.16)


SECTION 28. APPENDIX I: BRIDGE LOAD TESTING

28.1. Bridge Load Test Requirements

The load testing procedure eventually used for Quality control / Quality assurance process to ensure that partially finished members or the structure, as one unit, working safely.

The most prevalent deterioration factors are not due to catastrophic events such as seismic disturbance and typhoons, but rather are due to natural phenomena such as aging, overload, fatigue, weather and corrosion.

Some construction process may be affected with different factors which cause the structure to be finished without meeting the specification and material and dimensions required. Some of it is due to overloading during construction, fatigue and weather.

Assessing the condition of a structure is necessary to determine its safety and reliability. During the test, the deflection of member and strains along a vertical section of a beam should be measured by optical fiber bending gauges and strain gauges, respectively. Locating truck should be on different positions; that the induced bending moment on the measured section varies. The depth of neutral axis at the selected section should be estimated by strain data for each bending moment (truck’s position). Lastly, a recommended loading limit should be determined by combining the structure analysing with the physical test results.

Load test experiment may be required if the supervisor on the site feel that any element of the structure has to be tested, to check the all designed parameters are achieved during the construction. Also, after the construction has been finished, the supervisor can ask the contractor to perform the Load Test on the bridge to check that the structure is safe or not.

28.2. Results and Recommendation of Load Test

The bridge condition is usually affected by construction quality, aging if the construction stages are extended, overload, natural disaster, and is very likely different from the original design. The physical is a straightforward but practical solution to discover the real health condition of bridge. Through a field case of load test, a measuring technique that can continuously and smoothly describe the deflection curve of a deformed bridge can be done, and a back calculating for an acceptable load limit can demonstrate the condition. The fundamental idea of estimating the ultimate allowable bending moment is sticking to the linear behavior requirement, in other words, no nonlinear situation is approved.

Field tests can be completed with a readily available vehicle and the data can be used to calibrate a finite element model of the structure. Based on the field-calibrated model, accurate load ratings are determined as bellow:

- Evaluate effectiveness of strengthening and other repairs or replacement or reconstruction.
- Overload and permit loads.
- Accurate load ratings MOMRA HL-93 and any other design vehicles.
Whether you’re evaluating a steel, concrete, timber, or composite fiber bridge, expert team should be available to perform the test and confirm the reported recommendation.

28.3. Determining the Balancing Forces for Lift Bridges

The team of the experimental should be able to perform the test and determine the following:

- Shear strains on drive shafts using wireless transmitter
- Displacements at bridge corners
- Cable forces either with load cells or accelerometers
- Motor current draw

28.4. Structural Monitoring System Design

Few rules of “keeping it as simple as possible”, test should be configure the system with the least amount of hardware and sensors that collects the relevant information in the most efficient manner.

Data from any hardware should be at least as following:

- Monitor crack growth in concrete members
- Pier rotations due to scour (marine structures)
- Expansion joint displacements due to temperature fluctuations
- Fatigue cycle counting
- Overloaded vehicle weight enforcement

28.5. Load Test Report

The report of load test for example, should include at least and not limited, the following:

1. Preliminary Analysis
   A. Section Properties
   B. Beam Analysis
      B.1. Assumptions
      B.2. Allowable Stresses
      B.3. Prestress Losses
      B.4. Ultimate Moment Capacity
      B.5. Cracking Moment
      B.6. Maximum and Minimum Steel Percentages
      B.7. Feasible Solutions for Initial Prestress Force & Eccentricity

2. Instrumentation and Load Test Plans
   A. Instrumentation Plan
   B. Truck Weight and Dimensions
   C. Load Test Plan
   D. Estimated Load Effects

3. Analysis of the Test Results
   A. Load Distribution
   B. Neutral Axis Location
C. End Fixity Investigation
4. Load Rating Analysis
   A. Summary of Test Findings
   B. Proposed Test-Based Load Rating
5. Conclusion and Recommendations
This page is intentionally left blank
## SECTION 29. APPENDIX II: TABLE OF QUANTITIES

<table>
<thead>
<tr>
<th>Sequential Number</th>
<th>Items of Work</th>
<th>Units</th>
<th>Quantity</th>
<th>Price Per Unit</th>
<th>Total</th>
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<td>4</td>
<td>Structural Excavation And Backfill</td>
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<td>4.1.2.4</td>
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<td>Cubic Meter</td>
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<td>4.1.2.5</td>
<td>Unclassified Backfill, Select Backfill, and Granular Backfill</td>
<td>Cubic Meter</td>
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<td>4.1.2.6</td>
<td>Controlled Low-Strength Material (CLSM) Backfill</td>
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<td><strong>TOTAL</strong></td>
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<td>Removal of Existing Structures</td>
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<td>5.3.2</td>
<td>Partial Removal of Structures</td>
<td>Lump Sum</td>
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<td>5.3.3</td>
<td>Demolition</td>
<td>Contingent Sum</td>
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<td>5.3.4</td>
<td>Bridges, Culverts and other Existing Structures</td>
<td>Lump Sum</td>
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<td>5.3.5</td>
<td>Sewer Pipe</td>
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