STANDARD SPECIFICATIONS

for

HIGHWAY BRIDGES

The American Association of State Highway
and Transportation Officials

DIVISION II — CONSTRUCTION

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STANDARD SPECIFICATIONS

FOR

HIGHWAY BRIDGES

DIVISION II

CONSTRUCTION

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SECTION 28 - CONSTRUCTION AND INSTALLATION OF SOIL-REINFORCED CONCRETE STRUCTURE INTERACTION SYSTEMS

SECTION 1 - EXCAVATION AND FILL

1.1 GENERAL

1.1.1 Foundation excavation shall include the removal of all material, of whatever nature, necessary for the construction of foundations and substructures in accordance with the plans or as directed by the Engineer. It shall include the furnishing of all necessary equipment and the construction of all cribs, cofferdams, caissons, unwatering, etc., which may be necessary for the execution of the work. It shall also include the subsequent removal of cofferdams and cribs and the placement of all necessary backfill as hereinafter specified. It shall also include the disposing of excavated material, which is not required for backfill, in a manner and in locations so as not to affect the carrying capacity of any channel and not to be unsightly.

1.1.2 Unless the contract includes a separate payment item or items for such work, foundation excavation shall include removing old structures or parts thereof as required, and all necessary clearing and grubbing within the bridge site area. The bridge site is defined as the entire area between the right of way lines and between lines paralleling the bridge ends and passing through the longitudinal extremities of the substructure or superstructure, whichever is greater, unless a greater length is necessary for the required construction of the bridge, or unless otherwise specified in the contract.

1.1.3 All substructures, where practicable, shall be constructed in open excavation and, where necessary, the excavation shall be shored, braced, or protected by cofferdams in accordance with approved methods. When footings can be placed in the dry without the use of cribs or cofferdams, backforms may be omitted with the approval of the Engineer, and the entire excavation filled with concrete to the required elevation of the top of the footing. The additional concrete required shall be placed at the expense of the Contractor.

1.2 PRESERVATION OF CHANNEL

Unless otherwise specified, 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 excavation to the original ground surface or river bed with material satisfactory to the Engineer. Material deposited within the stream area from foundation or other excavation or from the filling of cofferdams shall be removed and the stream area freed from obstruction thereby.

1.3 DEPTH OF FOOTINGS

The elevation of the bottoms of footings, as shown on the plans, shall be considered as approximate only and the Engineer may order, in writing, such

changes in dimensions or elevation of footings as may be necessary to secure a satisfactory foundation.

1.4 PREPARATION OF FOUNDATIONS FOR FOOTINGS

1.4.1 All rock or other hard foundation material shall be freed from all loose material, cleaned and cut to a firm 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 grout before the masonry is placed.

1.4.2 When masonry is to rest on an excavated surface other than rock, special care shall be taken not to disturb the bottom of the excavation, and the final removal of the foundation material to grade shall not be made until just before the masonry is to be placed.

1.5 COFFERDAMS AND CRIBS

1.5.1 GENERAL

1.5.1.1 Cofferdams and cribs for foundation construction shall be carried to adequate depths and heights, 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, the interior dimensions of cofferdams and cribs shall be such as to give sufficient clearance for the construction of forms and the inspection of their exteriors, and to permit pumping outside the forms. Cofferdams or cribs which are tilted or moved laterally during the process of sinking shall be righted, reset, or enlarged so as to provide the necessary clearance and this shall be solely at the expense of the Contractor.

1.5.1.2 When conditions are encountered which, in the opinion of the Engineer, render it impracticable to unwater the foundation before placing masonry, he may require the construction of a concrete foundation seal of such dimensions as may be necessary. The foundation shall then be pumped out and the balance of the masonry placed in the dry. When weighted cribs 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 crib into the foundation seal. During the placing of a foundation seal, the elevation of the water inside the cofferdam 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 low water level.

1.5.2 PROTECTION OF CONCRETE

Cofferdams or cribs shall be constructed so as to protect green concrete against damage from a sudden rising of the stream and to prevent damage to the foundation by erosion. No timber or bracing shall be left in cofferdams or cribs in such a way as to extend into the substructure masonry, without written permission from the Engineer.

1.5.3 DRAWINGS REQUIRED

For substructure work, the Contractor shall submit, upon request, drawings showing his proposed method of cofferdam construction and other details left open to his choice or not fully shown on the Engineer's drawings. The Contractor shall not start cofferdam constuction until the Engineer has approved such drawings.

1.5.4 REMOVAL

Unless otherwise provided, cofferdams or cribs with all sheeting and bracing shall be removed after the completion of the substructure, care being taken not to disturb or otherwise injure the finished masonry.

1.6 PUMPING

1.6.1 Pumping from the interior of any foundation enclosure shall be done in such 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 for a period of at least 24 hours thereafter, unless it be done from a suitable sump separated from the concrete work by a watertight wall or other effective means.

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

1.7 INSPECTION

After each excavation is completed the Contractor shall notify the Engineer, and no masonry shall be placed until the Engineer has approved the depth of the excavation and the character of the foundation material.

1.8 BACKFILL

1.8.1 All material used for backfill shall be of a quality acceptable to the Engineer and shall be free from large or frozen lumps, wood, or other extraneous material.

1.8.2 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. All backfill shall be thoroughly compacted and, in general, its top surface shall be neatly graded.

1.8.3 The fill behind abutments and wingwalls of all bridge structures shall be deposited in well-compacted, horizontal layers not to exceed 12 inches in thickness. The backfill in front of such units shall be placed first to prevent the possibility of forward movement. Special precautions shall be taken to prevent any wedging action against the masonry, and the slope bounding the excavation for abutments and wingwalls shall be destroyed by stepping or roughening to prevent wedge action. Jetting of the fill behind abutments and wingwalls will not be permitted.

1.8.4 Fill placed around culverts and piers shall be deposited on both sides to approximately the same elevation at the same time.

1.8.5 Adequate provision shall be made for the thorough drainage of all backfilling. French drains shall be placed at weep holes.

1.8.6 No backfill shall be placed against any masonry abutment, wingwall, or culvert until permission shall have been given by the Engineer and preferably not until the masonry has been in place 14 days, or until test cylinders show the strength to be twice the working stress used in the design.

1.8.7 Backfilling of sectional plate pipes and arches shall be done in accordance with Articles 23.4, 5 and 6.

1.9 FILLED SPANDREL ARCHES

For filled spandrel arches, the filling shall be carefully placed in such manner as to load the ring uniformly and symmetrically. The filling material shall be acceptable to the Engineer and shall be placed in horizontal layers, not to exceed 12 inches in thickness, carefully tamped and brought up simultaneously from both haunches. Wedge shaped sections of filling material against spandrels, wings, or abutments will not be permitted.

1.10 APPROACH EMBANKMENT

When the contract for any bridge structure requires the placement of approach embankments, they shall be constructed and paid for in accordance with the highway specifications governing this class of construction. Unless otherwise provided in the contract, approach embankments shall be in place to the final ground lines before excavation for foundations in the embankments is started.

1.11 CLASSIFICATION OF EXCAVATION

Classification, if any, of excavation will be indicated on the plans and set forth in the proposal.

1.12 MEASUREMENT AND PAYMENT

1.12.1 Payment for foundation excavation shall include the cost of all labor, material, equipment, and other items that may be necessary or convenient to the successful completion of the excavation to the elevation of the bottom of the footings. It shall also include the cost of removing cofferdams and any surplus material which may have been thrown up during the process of excavation, and shall include the cost of backfilling in a compacted condition an amount of material equal to the amount of excavation. Any backfill in excess of the amount excavated shall be paid for as extra work unless a price for extra backfill is included in the contract.

1.12.2 The quantity to be paid for shall be the actual number of cubic yards of material, in original position, acceptably excavated in conformity with the plans or as directed by the Engineer, but no quantity shall be included in the measurement for payment which is outside of a volume bounded by vertical planes 18 inches outside of and parallel to the neat lines of the footing. The cross-sectional area measured shall not include water or other liquids, but shall include mud, muck, and other similar semi-solids.

1.12.3 The top and bottom limits of computed volume shall be the original ground or the top of the required grading cross section, whichever is lower, and the bottom of the completed footing.

1.12.4 When it is necessary, in the opinion of the Engineer, to carry the foundations below the elevations shown on the plans, the excavation for the first three feet of additional depth will be included in the quantity for which payment will be made under the item Foundation Excavation. Excavation below this additional depth will be paid for as extra work, unless the Contractor is willing to accept payment at contract prices.

SECTION 2 - SHEET PILES

2.1 GENERAL

This specification covers only sheet piling shown on the plans, or ordered by the Engineer, to be left in place so that it becomes a part of the finished structure.

2.2 TIMBER SHEET PILES

2.2.1 The timber, unless otherwise noted, shall be preservatively treated in accordance with Section 21, and may consist of any treatable species which will satisfactorily stand driving. It shall be sawn or hewn with square corners and shall be free from worm holes, loose knots, wind shakes, decayed or unsound portions, or other defects which might impair its strength or tightness.

2.2.2 The piles shall be of the dimensions shown on the plans either cut from the solid material or made by building up the piles of three planks securely fastened together. The piles shall be drift sharpened at their lower ends so as to wedge the adjacent piles tightly together.

2.2.3 The tops of the piles shall be cut off to a straight line at the elevation indicated and shall be braced with waling strips, properly lapped and joined at all splices and corners. The wales shall preferably be in one length between corners and shall be bolted near the tops of the piles.

2.3 CONCRETE SHEET PILES

Where concrete sheet piles are required, they shall be in strict accordance with the detailed design. The requirements governing the manufacture and installation of concrete sheet piling shall conform, in general, to those governing precast concrete bearing piles.

2.4 STEEL SHEET PILES

2.4.1 Steel sheet piles shall be of the type and weight indicated on the plans or designated in the special provisions and of the material required below. The piles, when in place in the completed structure, shall be practically watertight at the joints. Painting of steel sheet piles shall conform to Article 3.17.

2.4.2 Steel sheet piles shall conform to the requirements of AASHTO M 202 (ASTM A 328) or AASHTO M 223 (ASTM A 572) Grade 50.

2.5 MEASUREMENT AND PAYMENT

2.5.1 Payment for sheet piles shall include the cost of furnishing, driving, and cutting off. Payment will be made on the basis of the piles driven as approved by the Engineer, except that a deduction from

the payment will be made in an amount equal to the salvage value of the material cut off after driving.

2.5.2 Timber, concrete, and steel sheet piles will be paid for at the contract price per square foot.

SECTION 3 - BEARING PILES

3.1 MATERIALS

3.1.1 STEEL PILES

Steel piles shall consist of structural steel shapes of the section provided on the plans or as otherwise specified. The steel shall conform to the Specification for Structural Steel, AASHTO M 183 (ASTM A 36).

3.1.2 TIMBER PILES

Timber piles shall conform to the requirements of the Specification for Wood Products, AASHTO M 168. Timber piles shall be treated or untreated as indicated in the contract.

3.1.3 CONCRETE PILES

Concrete piles shall be manufactured as specified herein.

3.2 DESIGN AND CONDITIONS OF USE

General and Design: Refer to Division 1, Section 4.
Bearing Values, Design: Refer to Division 1, Article 4.2.
Preservative Treatment: Refer to Section 21.

3.3 PREPARATION FOR DRIVING

3.3.1 EXCAVATION

In general, piles shall not be driven until after the excavation is complete. Any material forced up between the piles shall be removed to correct elevation without cost to the owner before masonry for the foundation is placed.

3.3.2 CAPS

3.3.2.1 The heads of all concrete piles and the heads of timber piles, when the nature of the driving is such as to unduly injure them, shall be protected by caps of approved design, preferably having a rope or other suitable cushion next to the pile head and fitting into a casting which in turn supports a timber shock block. When the area of the head of any timber pile is greater than that of the face of the hammer, a suitable cap shall be provided to distribute the blow of the hammer throughout the cross section of the pile.

3.3.2.2 The head shall be cut square and shall be shaped or chamfered to prevent splitting at its periphery.

3.3.2.3 Special types of piling, driving heads, or other devices, in accordance with the manufacturers' recommendation, shall be provided so that the pile may be driven without injury.

3.3.2.4 For steel piling, the heads shall be cut squarely, and a driving cap shall be provided to hold the axis of the pile in line with the axis of the hammer.

3.3.3 COLLARS

Collar, bands, or other devices shall be provided where necessary to protect timber piles against splitting and brooming.

3.3.4 POINTING

Timber piles shall be pointed where soil conditions require it. When necessary, the piles shall be shod with metal shoes of a design satisfactory to the Engineer, the points of the piles being carefully shaped to secure an even and uniform bearing on the shoes.

3.3.5 SPLICING PILES

Full length piles shall be used where practicable. In exceptional circumstances splicing of piles may be permited. The method of splicing shall be as shown on the plans or as approved by the Engineer. When the splicing of steel piles or steel shells of special piles is done by welding, the arc method shall be given preference. Welding shall be performed only by approved experienced welders.

3.3.6 PAINTING STEEL PILES

Steel piles shall be painted as specified in Article 3.17.

3.4 METHODS OF DRIVING

3.4.1 GENERAL

Piles may be driven with a gravity hammer, a steam hammer, or a combination of water jets and hammer, but a steam hammer is preferred. Precast concrete piles, preferably, shall be driven by means of a combination of hammer and jet. Hammers shall deliver proper energy to drive the piles without injury to the piles.

3.4.2 HAMMERS FOR TIMBER AND STEEL PILES

Gravity hammers for driving timber piles shall weigh not less than 2,000 pounds, preferably 3,000 pounds, and for steel piles not less than 3,000 pounds, but in no case shall the weight of the hammer be less than the combined weight of driving head and pile. The fall shall be so regulated as to avoid injury to the piles and in no case shall exceed 15 feet. When a steam hammer is used, the total energy developed by the hammer shall be not less than 6,000 foot-pounds per blow.

3.4.3 HAMMERS FOR CONCRETE PILES

3.4.3.1 Unless otherwise provided, concrete piles, precast, or shells for cast-in-place piles, shall be driven with a steam hammer which shall develop an energy per blow at each full stroke of the piston of not less than one foot-pound for each pound of weight driven. In no case shall the total energy developed by the hammer be less than 6,000 foot-pounds per blow.

3.4.3.2 If a gravity hammer is used, it shall have a weight not less than 50 percent of the weight of the pile, but in no case less than 3,000 pounds, and the drop of the hammer shall not exceed 8 feet.

3.4.4 ADDITIONAL EQUIPMENT

In case the required penetration is not obtained by the use of a hammer complying with the above minimum requirements, the Contractor shall provide a heavier hammer or resort to jetting at his own expense.

3.4.5 LEADS

Pile driver leads shall be constructed in such a manner as to afford freedom of movement of the hammer, and they shall be held in position by guys or stiff braces to insure support to the pile during driving. Except where piles are driven through water, the leads, preferably, shall be of sufficient length so that the use of a follower will not be necessary.

Preferably, inclined leads shall be used in driving battered piles.

3.4.6 FOLLOWERS

The driving of piling with followers shall be avoided if practicable and shall be done only under written permission of the Engineer. When followers are used, one pile from each group of 10 shall be a long pile driven without a follower and shall be used as a test pile to determine the average bearing power of the group.

3.4.7 WATER JETS

When water jets are used, the number of jets and the volume and pressure of water at the jet nozzles shall be sufficient to freely erode the material adjacent to the pile. The plant shall have sufficient capacity to deliver at all times at least 100 pounds per square inch pressure at two 3/4 inch jet nozzles. Before the desired penetration is reached, the jets shall be withdrawn and the piles shall be driven with the hammer to secure the final penetration.

3.4.8 ACCURACY OF DRIVING

Piles shall be driven with a variation of not more than 1/4 inch per foot from the vertical or from the batter shown on the plans, except that piles for trestle bents shall be so driven that the cap may be

placed in its proper location without inducing excessive stresses in the piles, and foundation piles shall not be out of the position shown on the plan more than 6 inches after driving.

3.5 DEFECTIVE PILES

3.5.1 The procedure incident to the driving of 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 deformation of the steel. Manipulation of piles to force them into proper position, considered by the Engineer to be excessive, will not be permitted. Any pile damaged by reason of internal defects or by improper driving or driven out of its proper location or driven below the elevation fixed by the plans or by the Engineer shall be corrected at the Contractor's expense by one of the following methods approved by the Engineer for the pile in question:

3.5.1.1 The pile shall be withdrawn and replaced by a new and, if necessary, a longer pile.

3.5.1.2 A second pile shall be driven adjacent to the defective or low pile.

3.5.1.3 The pile shall be spliced or built up as otherwise provided herein or a sufficient portion of the footing extended to properly embed the pile. Timber piles shall not be spliced without specific permission of the Engineer. All piles pushed up by the driving of adjacent piles or by any other cause shall be driven down again.

3.6 DETERMINATION OF BEARING VALUES (See also Division 1, Article 4.2)

3.6.1 LOADING TESTS

3.6.1.1 When required, the size and number of piles shall be determined by actual loading tests. In general, these tests shall consist of the application of a test load placed upon a suitable platform supported by the pile with suitable apparatus for accurately measuring the test load and the settlement of the pile under each increment of load.

3.6.1.2 In lieu thereof, hydraulic jacks with suitable yokes and pressure gauges may be used.

3.6.1.3 The safe allowable load shall be considerd as 50 percent of that load which, after a continuous application of 48 hours, produces a permanent settlement not greater than 1/4 inch measured at the top of the pile. This maximum settlement shall not be increased by a continuous application of the test load for a period of 60 hours or longer.

3.6.1.4 At least one pile for each group of 100 piles preferably should be tested.

3.6.2 TIMBER PILE FORMULAS

3.6.2.1 When not driven to practical refusal, the bearing values of piles preferably shall be determined by load tests as specified above. In the absence of loading tests or substantiated adequate pile formulas, the safe bearing values for timber piles shall be determined by the following formulas:

$$P = \frac{2WH}{S+1.0} \quad \text{for gravity hammers} \qquad (3\text{-}1)$$

$$P = \frac{2WH}{S+0.1} \quad \text{for single-acting steam hammers} \qquad (3\text{-}2)$$

$$P = \frac{2H(W+Ap)}{S+0.1} \quad \text{for double-acting steam hammers} \qquad (3\text{-}3)$$

where

P = safe bearing capacity in pounds,
W = weight, in pounds of striking parts of hammer,
H = height of fall in feet,
A = area of piston in square inches,
p = steam pressure in pounds per square inch at the hammer,
S = the average penetration in inches per blow for the last 5 to 10 blows for gravity hammers and the last 10 to 20 blows for steam hammers.

The above formulas are applicable only when --

The hammer has a free fall.
The head of the pile is not broomed or crushed.
The penetration is reasonably quick and uniform.
There is no sensible bounce after the blow.
A follower is not used.

Twice the height of the bounce shall be deducted from "H" to determine its value in the formula.

Unless otherwise ordered by the Engineer, timber piling shall be driven to the bearing value given on the plans or in the supplemental specifications. If bearing values are not given, timber piling shall be driven to a minimum value of twenty tons.

In case water jets are used in connection with the driving, the bearing capacity shall be determined by the above formulas from the results of driving after the jets have been withdrawn, or a load test may be applied.

3.6.3 CONCRETE AND STEEL PILES

When not driven to practical refusal, the bearing value for concrete and steel piles preferably shall be determined by means of loading

tests specified above. In the absence of loading tests, their safe bearing values may be approximated by substantiated adequate pile formulas or those specified for timber piles. However, the character of the soil penetrated, conditions of driving, distribution, size, length and weight of the piles, shells or cores driven, and the computed load per pile shall be given due consideration in determining their probable safe bearing value.

3.7 TEST PILES

When required, the Contractor shall drive test piles of a length and at the location designated by the Engineer. These piles shall be of greater length than the length assumed in the design in order to provide for any variation in soil conditions.

3.8 ORDER LISTS FOR PILING

3.8.1 The Contractor shall furnish piles in accordance with an itemized list, which shall be furnished by the Engineer, showing the number and length of all piles.

3.8.2 In determining lengths of piles for ordering and for footage to be included in the contract, the lengths given in the order list shall be based on the lengths which are assumed to remain in the completed structure. The Contractor shall, at his own expense, increase the lengths given to provide for fresh heading and for such additional length as may be necessary to suit the Contractor's method of operation.

3.9 STORAGE AND HANDLING OF TIMBER PILES

The method of storing and handling shall be such as to avoid injury to the piles. Special care shall be taken to avoid breaking the surface of treated piles. Cant-hooks, dogs, or pike-poles shall not be used. Cuts or breaks in the surface of treated piling shall be given three brush coats of hot creosote oil of approved quality, and hot creosote oil shall be poured into all bolt holes.

3.10 CUTTING OFF TIMBER PILES

The tops of all piling shall be sawed to a true plane, as shown on the plans, and at the elevation fixed by the Engineer. Piles which support timber caps or grillage shall be sawed to conform to the plane of the bottom of the superimposed structure. In general, the length of pile above the elevation of cut-off shall be sufficient to permit the complete removal of all material injured by driving, but piles driven to very nearly the cut-off elevation shall be carefully adzed or otherwise freed from all "broomed," splintered, or otherwise injured material.

3.11 CUTTING OFF STEEL OR STEEL SHELL PILES

Piles shall be cut off at the required elevation. If capping is required, the connection shall be made according to details shown on the plans.

3.12 CAPPING TIMBER PILES

After cut-off, the heads of timber piles shall be protected as specified in Article 20.7.

3.13 MANUFACTURE OF PRECAST CONCRETE PILES

3.13.1 GENERAL

Piles shall be constructed in accordance with details shown on the plans.

3.13.2 CLASS OF CONCRETE

Class A or A(AE) concrete shall be used for precast concrete piles.

3.13.3 FORM WORK

Forms for precast concrete piles shall conform to the general requirements for concrete form work as provided in Article 4.20. Forms shall be accessible for tamping and consolidation of the concrete. Under good weather curing conditions, side forms may be removed at any time not less than 24 hours after placing the concrete, but the entire pile shall remain supported for at least seven days and shall not be subjected to any handling stress until the concrete has set for at least 21 days, and for a longer period in cold weather, the additional time to be determined by the Engineer.

3.13.4 REINFORCEMENT

Reinforcement shall be placed in accordance with details shown on the plans.

3.13.5 CASTING

3.13.5.1 The piles may be cast in either a horizontal or a vertical position. Special care shall be taken to place the concrete so as to produce satisfactory bond with the reinforcement and

avoid the formation of "stone pockets," honeycomb, or other such defects.

3.13.5.2 To secure uniformity and remove surplus water, the concrete in each pile shall be placed continuously and shall be compacted by vibrating or by other means acceptable to the Engineer. The forms shall be overfilled, the surplus concrete screeded off, and the top surfaces finished to a uniform, even texture similar to that produced by the forms.

3.13.6 FINISH

Trestle piling exposed to view shall be finished above the ground line in accordance with the provisions governing the finishing of concrete columns. Foundation piling, that portion of the trestle piling which will be below the ground surface, and piles for use in sea water or alkali soils, shall not be finished except as set forth above.

3.13.7 CURING

Concrete piles shall be cured as provided elsewhere in these specifications for concrete. As soon as the piles have set sufficiently, they shall be removed from the forms and piled in a curing pile separated from each other by wood spacing blocks. No pile shall be driven until it has set for at least 21 days and, in cold weather, for a longer period as determined by the Engineer. Concrete piles for use in sea water or alkali soils shall be cured for not less than 30 days before being used.

3.14 STORAGE AND HANDLING OF PRECAST CONCRETE PILES

3.14.1 Removal of forms, curing, storing, transporting, and handling precast concrete piles shall be done in such a manner as to avoid excessive bending stresses, cracking, spalling, or other injurious results. The method of handling shall be such as will not induce stresses exceeding those specified in Division 1, Section 8 when computed according to Division 1, Article 4.3.

3.14.2 Piles to be used in sea water or in alkali soils shall be handled so as to avoid surface abrasions or other injuries exposing the interior concrete.

3.15 MANUFACTURE OF CAST-IN-PLACE CONCRETE PILES

3.15.1 GENERAL

Piles shall be constructed in accordance with details shown on the plans.

3.15.2 INSPECTION OF METAL SHELLS

At all times prior to the placing of concrete in the driven shells, the Contractor shall have available a suitable light for the inspection of each shell throughout its entire length. Any improperly driven,

broken, or otherwise defective shell shall be corrected to the satisfaction of the Engineer by removal and replacement, or the driving of an additional pile, at no extra cost.

3.15.3 CLASS OF CONCRETE

Class A or A(AE) concrete shall be used for cast-in-place piles.

3.15.4 REINFORCEMENT

Reinforcement shall be placed in accordance with the plans or special provisions.

3.15.5 PLACING CONCRETE

3.15.5.1 No concrete shall be placed until all driving within a radius of 15 feet has been completed, nor until all the shells for any one bent have been completely driven. If this cannot be done, all driving within the above limits shall be discontinued until the concrete in the last pile cast has set at least seven days.

3.15.5.2 Concrete shall be placed as specified for piles precast in the vertical position. Accumulations of water in shells shall be removed before the concrete is placed. After the concrete has hardened, the top surface shall be cut back to remove laitence and to expose the aggregate as detailed in Article 4.15.2.

3.16 EXTENSIONS OR "BUILD-UPS"

3.16.1 Extensions, splices, or "build-ups" on concrete piles, when necessary, shall be made as follows:

3.16.1.1 After the driving is completed, the concrete at the end of the pile shall be cut away, leaving the reinforcement steel exposed for a length of 40 diameters. The final cut of the concrete shall be perpendicular to the axis of the pile. Reinforcement similar to that used in the pile shall be securely fastened to the projecting steel and the necessary form work shall be placed, care being taken to prevent leakage along the pile. The concrete shall be of the same quality as that used in the pile. Just prior to placing concrete, the top of the pile shall be thoroughly wetted and covered with a thin coating of neat cement, retempered mortar, or other suitable bonding material. The forms shall remain in place not less than seven days and shall then be carefully removed and the entire exposed surface of the pile finished as previously specified.

3.17 PAINTING STEEL PILES AND STEEL PILE SHELLS

Unless otherwise provided, when steel piles or steel pile shells extend above the ground surface or water surface they shall be protected by three coats of paint as specified for Painting Metal Structures in Section 14. This protection shall extend from an elevation 2 feet below the water or ground surface to the top of the exposed steel.

3.18 MEASUREMENT AND PAYMENT

3.18.1 GENERAL

Piling, whether timber, concrete, or steel, will be paid for according to Method A or B as designated in the contract.

3.18.2 METHOD A

For furnishing and driving piles at the contract price per linear foot.

3.18.2.1 CUTOFF

The total cutoff of piling shall be paid for at the prices set forth in the special provision for those of the following items incorporated in the work:

Cutoff, untreated timber piles, per linear foot	$ .....
Cutoff, treated timber piles, per linear foot	$ .....
Cutoff, precast concrete piles, per linear foot	$ .....
Cutoff, steel shells for piles, per linear foot	$ .....
Cutoff, steel piles, per pound	$ .....

3.18.2.2 FURNISHING AND DRIVING

The number of linear feet to be paid for shall be the actual length of piles remaining in the completed structure, and the number of linear feet of cutoff to be paid for shall be the actual number of linear feet cutoff, except that no allowance will be made for lengths in excess of those ordered by the Engineer, and except that if the Contractor casts concrete piles full length of the reinforcement bars to facilitate driving, no payment will be made for that portion where concrete must be removed in order that bars may project as shown on the plans. If paid for as "cutoff," cutoff material (if the cutoff is in excess of 3 feet in length) shall become the property of the State. Cutoff material 3 feet or less in length, and other cutoff material which, in the opinion of the Engineer, is not worth salvaging, shall be disposed of to the satisfaction of the Engineer.

3.18.2.3 PAYMENT FOR FURNISHING AND DRIVING PILES

Payment for furnishing and driving piles shall include the material and work specified under "Payment for Furnishing Piles" and "Payment for Driving Piles" -- Method B.

3.18.3 METHOD B

For furnishing piles at the contract price per linear foot and for driving piles at the contract price per linear foot.

3.18.3.1 FURNISHING

The number of linear feet of timber, precast concrete, or steel piles to be paid for shall be the total ordered length of piles which are driven and which have been furnished in accordance with the lengths designated by the Engineer, except that if the Contractor casts concrete piles full length of the reinforcement bars to facilitate driving, no payment will be made for that portion where concrete must be removed in order that bars may project as shown on the plans. Cutoff material 3 feet or less in length and other cutoff material which, in the opinion of the Engineer, is not worth salvaging, shall be disposed of to the satisfaction of the Engineer.

The number of linear feet of cast-in-place piles to be paid for shall be the actual number of linear feet of piles remaining in the completed structure. The length measured shall include both the steel-shell and the reinforced concrete extension as measured from the point of the tip of the pile to the bottom of the cap or bottom of the footing, as the case may be.

3.18.3.2 DRIVING

The number of linear feet to be paid for shall be the total number of linear feet of piling remaining in the completed structure. For driving cast-in-place piles the length measured shall include both the steel shell and the reinforced concrete extensions as measured from the point of the tip of the pile to the bottom of the cap or bottom of the footing, as the case may be.

3.18.3.3 PAYMENT FOR FURNISHING PILES

Payment for furnishing piles shall include full compensation for furnishing the piling and all material required therefor ready for placement, including all material necessary for extensions and build-ups and for completion of the pile, and for all labor, tools, hauling, equipment, handling, treatment, and all work incidental to the construction of the piling prior to driving or construction of build-ups and extensions. Payments shall also include (a) reinforcement in concrete piles required to extend beyond the end of the pile for connections; (b) the fitting and attaching of steel shoes when they are specified for timber piles; (c) the furnishing and attaching of brackets, lugs, core stoppers, and cap plates on steel piling.

3.18.3.4 PAYMENT FOR DRIVING PILES

Payment for driving piles per linear foot shall include full compensation for furnishing all labor, tools, materials, supplies, equipment, and other necessary or incidental costs of handling, driving, cutting off piles, treatment of pile heads, constructing build-ups, and extensions of concrete piles, painting of steel piles, and all other incidental work connected therewith. It

shall also include full compensation for all jetting, drilling, blasting, or other work necessary to obtain the required penetration or bearing values of piles.

3.18.4 FALSEWORK AND DEFECTIVE PILES

No payment will be made for the furnishing or driving of falsework piles, nor will payment be made for piles driven out of place, for defective piles, or for piles which are damaged in handling or driving.

3.18.5 ADDITIONAL REQUIREMENTS

3.18.5.1 If the length of wood piles, steel piles, or steel pile shells designated by the Engineer is not sufficient, the splicing, including labor, equipment, and material, shall be paid for on the basis of extra work unless a contract item is provided to cover the payment.

3.18.5.2 Brackets, plates, or other reinforcement on steel piles required by the Engineer in addition to those shown on the plans will be paid for as extra work.

3.18.5.3 If not covered by a contract item, metal shoes for piling, ordered by the Engineer, will be paid for at cost delivered to the site, plus 15 percent.

3.18.5.4 No additional allowance or adjustment will be made in the contract prices for furnishing or driving piling because of these additional requirements.

3.19 PAYMENT FOR TEST PILES

Test piles ordered by the Engineer shall be paid for as follows:

3.19.1 If piles are used in the structure as a result of the test, the test piles shall be paid for as in the case of other piles.

3.19.2 If, however, piling is not used in the structure, the test piles will be paid for as provided for extra work, due consideration being given to the cost of bringing the pile driver to the site and removing it from the work.

3.20 PAYMENT FOR LOADING TESTS

Payment for loading tests shall include the cost of all material, equipment, and labor incidental to making the loading test or tests as directed by the Engineer, or as specified in the special provisions. Payment shall be made on the basis of the contract price for pile loading tests or, in the absence of such a price, shall be made on the basis of extra work.

SECTION 4 - CONCRETE STRUCTURES

4.1 DESCRIPTION

4.1.1 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 plans. Concrete shall consist of a mixture of Portland cement, fine aggregate, coarse aggregate, additives when required, and water mixed in the proportions specified or approved.

4.1.2 In order to avoid repetition, any expression using "permitted, approval, approved, directed, etc.," shall be interpreted as if followed by the words "by the Engineer."

4.2 MATERIALS

4.2.1 PORTLAND CEMENT

4.2.1.1 Portland cement shall conform to the requirements of the following cited specifications. Unless otherwise specified, Type I Portland Cement or Type IA Air-Entraining Portland Cement shall be used.

Type	Specification
Portland Cement	AASHTO M 85
Air-Entraining Portland Cement	AASHTO M 85
Portland Blast-Furnace Slag Cement	AASHTO M 240 (ASTM C 595)
Air-Entraining Portland Blast-Furnace Slag Cement	AASHTO M 240
Masonry Cement	AASHTO M 150 (ASTM C 91)

4.2.1.2 Unless otherwise permitted, the product of only one mill of any one brand and type of Portland cement shall be used on the project, except for reduction of any excessive air-entrainment where air-entraining cement is used.

4.2.2 WATER

4.2.2.1 Water used in mixing and curing of concrete shall be subject to approval and shall be reasonably clean and free of oil, salt, acid, alkali, sugar, vegetable, or other substance injurious to the finished project. Water will be tested in accordance with, and shall meet the suggested requirements of AASHTO T 26. Water known to be of potable quality may be used without test. Where the source of water is relatively shallow, the intake shall be so enclosed as to exclude silt, mud, grass, or other foreign materials.

4.2.2.2 When comparative compressive tests are made in conformance with AASHTO T 106 (ASTM C 109), any indication of unsoundness, marked change in time of setting, or a reduction of more than 10 percent in mortar strength, shall be sufficient cause for rejection of the water under test.

4.2.2.3 Mixing water shall not contain a chloride ion concentration in excess of 1000 ppm for conventionally reinforced concrete. If concrete contains aluminum embedments the concentration shall not exceed 200 ppm.

4.2.3 FINE AGGREGATE

Fine aggregate for concrete shall conform to the requirements of AASHTO M 6.

4.2.4 COARSE AGGREGATE

Coarse aggregate for concrete shall conform to the requirements of AASHTO M 80.

4.2.5 LIGHTWEIGHT AGGREGATE

Lightweight aggregate for concrete shall conform to the requirements of AASHTO M 195.

4.2.6 AIR-ENTRAINING ADMIXTURES

Air-entraining admixtures shall conform to the requirements of AASHTO M 154 (ASTM C 260).

4.2.7 RETARDING AGENT

4.2.7.1 In order to permit the retarding of the set and extend the finishing time of concrete, a retarding agent shall be used when specified on the plans or may be used when permission for its use is requested by the Contractor in writing, and such permission is given. The retarding agent shall be a Type B or Type D admixture as defined in AASHTO M 194 (ASTM C 494). The Contractor shall support his request with a manufacturer's certified formulation of the proposed agent and with sufficient evidence that the proposed agent has given satisfactory results on other similar work. Permission to use the agent may be withdrawn at any time when unsatisfactory results are obtained.

4.2.7.2 The agent shall be free of calcium chloride. When air-entrained concrete is specified, the air-entraining agent and the retarding agent shall be so incorporated that the air content of the concrete shall fall within the percentage range stipulated in the specifications. When air-entrained concrete is not specified, the concrete to which the retarding agent has been added shall have an air content not greater than three percent except as recommended for bridge decks.

4.2.7.3 The Contractor shall incorporate the retarding agent in water solution and the water so included shall be calculated as effective mix water.

4.2.7.4 No compensation will be made for furnishing and incorporating the agent in the mix. No additional compensation will be made for furnishing, placing, finishing, and curing the concrete involved.

4.2.8 RUBBLE OR CYCLOPEAN AGGREGATE

4.2.8.1 One-man and derrick stone used in rubble or cyclopean concrete shall consist of tough, sound, and durable rock. The stone shall be free from coatings, drys, seams, or flaws of any character. In general, the percentage of wear shall not exceed 50 when tested in accordance with Standard Method of Test for Abrasion of Coarse Aggregate by the use of the "Los Angeles Machine", ASTM C 535.

4.2.8.2 Preferably, stone shall be angular in shape and shall have a rough surface such as will thoroughly bond with the surrounding mortar.

4.2.9 CURING MATERIALS

Curing materials shall conform to the following requirements:

Sheet Materials for Curing Concrete	AASHTO M 171 (ASTM C 171)
Burlap Cloth made from Jute or Kenaf	AASHTO M 182
Liquid Membrane-Forming Compounds for Curing Concrete	AASHTO M 148 (ASTM C 309)

4.3 CARE AND STORAGE OF CONCRETE AGGREGATES

4.3.1 The handling and storage of concrete aggregates shall be such as to prevent segregation or the admixture of foreign materials. The Engineer may require that aggregates be stored on separate platforms at satisfactory locations.

4.3.2 When specified in Article 4.6 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. 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.

4.4 STORAGE OF CEMENT

4.4.1 All bulk cement shall be stored in a metal silo, bin, or other approved storage to protect the cement from dampness and from contamination. Provisions for storage shall be ample. Provisions for purposes of sampling and inspection of the cement shall be provided.

4.4.2 All sacked cement shall be stored in suitable weatherproof buildings; however, if approved, sacked cement on small jobs may be stored in the open upon a raised platform provided that ample waterproof covering is provided.

4.4.3 Copies of cement records shall be furnished to the Engineer, showing, in such detail as he may reasonably require, the quantity used during the day or run at each part of the work. Cement held in storage for a period of over 60 days, 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.

4.5 CLASSES OF CONCRETE

4.5.1 Eight classes of concrete are provided for in these specifications. Each class of concrete shall be used in that part of the structure where called for on the plans or where designated by the Engineer. The classes are as follows:

Class A	Class A (AE)
Class B	Class B (AE)
Class C	Class C (AE)
Class P	
Seal	

The classes of concrete will generally be used as follows:

4.5.2 Class A or Class A (AE) concrete will generally be used for all superstructures, except as noted below, and for heavily reinforced substructures. The more important items of work included are slabs, beams, girders, columns, arch ribs, box culverts, reinforced abutments, retaining walls, reinforced footings, precast piles, and cribbing. Class A (AE) concrete will generally be used in all locations (especially bridge decks) where the concrete will be exposed to severe or moderate natural weathering (alternate freezing and thawing) as well as in concrete exposed to salt water action.

4.5.3 Class B or Class B (AE) concrete shall be used in footings, pedestals, massive pier shafts, and gravity walls, with none or only a small amount of reinforcement.

4.5.4 Class C or Class C (AE) concrete shall be used in thin reinforced sections for handrails except as specified for precast railing under "Railings" and for filler in steel grid floors. Class C (AE) concrete will generally be used in locations where the concrete will be exposed to severe or moderate weather (alternate freezing and thawing).

4.5.5 Seal concrete will generally be used for concrete deposited in water and Class P concrete will generally be used for prestressed concrete members.

4.6 PROPORTIONING OF CONCRETE

4.6.1 The concrete mixture shall be proportioned so as to secure a workable, finishable, durable, watertight, and wear resistant concrete of the desired strength.

4.6.2 The concrete materials shall be proportioned using the absolute volumes method in accordance with the requirements for each class as specified in Table 4.1. The mix shall be designed or the design approved by the Engineer.

4.6.3 For structural lightweight concrete, the mix proportions shall be selected on the basis of trial mixes with the required strength based on cement factor rather than water-cement ratio. The mix design shall be submitted for approval.

4.7 SAMPLING AND TESTING

4.7.1 Compliance with the requirements indicated in Article 4.6 shall be determined in accordance with the following standard methods of AASHTO:

4.7.1.1	Sampling Fresh Concrete	T 141 (ASTM C 172)
4.7.1.2	Weight per Cubic Foot, Yield and Air Content (Gravimetric) of Concrete	T 121 (ASTM C 138)
4.7.1.3	Sieve Analysis of Fine and Coarse Aggregate	T 27
4.7.1.4	Slump of Portland Cement Concrete	T 119 (ASTM C 143)
4.7.1.5	Air Content of Freshly Mixed Concrete by the Pressure Method	T 152 (ASTM C 231)
4.7.1.6	Specific Gravity and Absorption of Fine Aggregate	T 84 (ASTM C 128)
4.7.1.7	Specific Gravity and Absorption of Coarse Aggregate	T 85
4.7.1.8	Unit Weight of Structural Lightweight Concrete	ASTM C 567
4.7.1.9	Making and Curing Concrete Test Specimens in the Laboratory	T 126 (ASTM C 192)

4.7.2 Tests for strength shall be made in accordance with the following:

4.7.2.1 Making and curing concrete compressive and flexural test specimens in the field. AASHTO T 23 (ASTM C 31).

4.7.2.2 Compressive strength of molded concrete cylinders. AASHTO T 22 (ASTM C 39).

4.7.3 Samples for strength tests of each class of concrete shall be taken not less than once a day nor less than once for each 100 cubic yards of concrete or once for each major pour. Strength tests of specimens cured under field conditions for the concrete used for bridge

Table 4.1

Class of Concrete	Minimum Cement Factor Sack Per C.Y.	Maximum Net Water Content Per Sack (L94-) of Cement Gallons[c]	Air Content Range Percent	Designated Size (No.) of Coarse Aggregates AASHTO M 80 Square Openings	Design Compression Strength (28 Days) lb/in^2
A	6.5	5.5	[a]	1" to No. 4	4,000
A(AE)	6.5	5.0	6±1	1" to No. 4	4,500
B	5.5	6.5	---	2" to No. 3[b] and 1" to No. 4[b]	2,200
B(AE)	5.5	6.5	5±1		2,200
C	7.0	5.5	6±1	1/2" to No. 4	4,000
C(AE)	7.0	5.0	8.5±1	1/2" to No. 4	4,500
P	6.0	5.5	---	1" to No. 4	As specified on plans
Seal	6.0	6.5	---	1" to No. 4	2,200

[a]When this class of concrete is used for bridge decks an air content range of 4 ± 1% is recommended.

[b]Coarse Aggregate for Class B and Class B(AE) shall be furnished in two separate sizes as shown.

[c]Conversion based on 94-pound sack.

decks shall be carried out to check the adequacy of curing and protection of the concrete. Strength tests of field cured specimens may be required for concrete used in other parts of the structure. Each strength test result shall be the average of at least two cylinders from the same sample test at 28 days or the specified earlier age. At least four strength tests shall be made for each class of concrete on any project unless waived by the Engineer. The cylinders shall be cured under conditions which are not more favorable than the most unfavorable conditions for the portions of the concrete which they represent.

4.7.4 For the strength level of the concrete to be considered satisfactory, all strength test results shall equal or exceed the minimum compressive strength shown in Table 4.1 and the strength of no individual cylinder shall be less than 85 percent of the minimum compressive strength. If higher compressive strength mixes are specified the test procedures for acceptance of these mixes shall also be specified.

4.8 MEASUREMENT OF MATERIALS

4.8.1 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 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 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. All measuring devices shall be subject to approval.

4.8.2 When volumetric measurements are authorized for projects where the amount of concrete is small, 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.

4.8.3 When the aggregates contain more water than the quantity necessary to produce a saturated surface-dry condition as contemplated in Article 4.6, representative samples shall be taken and the moisture content determined for each kind of aggregate. When sack 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.

4.9 MIXING CONCRETE

4.9.1 GENERAL

4.9.1.1 The concrete shall be mixed only in the quantity required for immediate use. Concrete that has developed an initial set shall not be used.

4.9.1.2 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. Upon the cessation of mixing for a considerable period, the mixer shall be thoroughly cleaned.

4.9.1.3 Concrete may be mixed at the site of construction, at a central point, or wholly or in part in truck mixers. The production of ready-mixed concrete shall meet the requirements of, and the production of site-mixed concrete shall meet the applicable requirements of, AASHTO M 157, with the following additional requirements.

(a) 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.

(b) Retempering concrete by adding water or by other means will not be permitted. Concrete that is not within the specified slump limits at time of placement shall not be used. Admixtures for increasing the workability or for accelerating the set will be permitted only when specifically provided for in the contract, or when directed.

4.9.2 DELIVERY

The organization supplying concrete shall have sufficient plant capacity and transporting apparatus to insure 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. 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.

4.10 WEATHER AND TEMPERATURE LIMITATIONS - PROTECTION OF CONCRETE

4.10.1 The temperature of the concrete mixture immediately before placement shall be between 50F and 90F.

4.10.2 When the ambient temperature is above 90F, the forms, reinforcing steel, steel beam flanges, and other surfaces which will come in contact with the mix shall be cooled to below 90F by means of a water spray or other approved methods.

4.10.3 No concrete shall be placed when the air temperature is below 35F unless provision is made for heating the ingredients and for

enclosing the concrete and heating the enclosures. No concrete shall be placed when the weather forecasts indicate air temperature below 32F during the succeeding five days unless provision is made for enclosing the concrete and heating the enclosure. Insulated forms may be used provided they have prior approval.

4.10.4 When concrete is placed at air temperature below 35F the ingredients shall be heated so that the temperature of the concrete when placed shall be not less than 60F.

4.10.5 Heating equipment or methods which alter or prevent the entrainment of the required amount of air in the concrete shall not be used. The equipment shall be capable of heating the materials uniformly. Aggregates and water used for mixing shall not be heated to a temperature exceeding 150F. Materials containing frost or lumps of frozen material shall not be used.

4.10.6 Stockpiled aggregates may be heated by the use of dry heat or steam. Aggregates shall not be heated directly by gas or oil flame or on sheet metal over fire.

4.10.7 Aggregates heated in bins, steam-coil heating, water-coil heating, or other methods which will not be detrimental to the aggregates, may be used. The use of live steam on or through binned aggregates will not be permitted.

4.10.8 The concrete shall be enclosed immediately after placing and the concrete and air in the enclosure kept above 50F for a period of five days. When dry heat is used, curing shall be in accordance with Article 4.22. If wet steam is used for heating, the time may be reduced to a minimum of 48 hours provided that the temperature of the concrete and air in the enclosure is held above 75F. If protected in this manner, the concrete shall be covered with cotton mats or three thicknesses of nine ounce burlap or other approved material after the enclosure is removed and the covering shall remain in place for a total period of five days after placing the concrete.

4.10.9 When concrete is placed and weather forecasts during the succeeding 5 days indicate air temperatures below 32F, the concrete shall be enclosed and protected in the same manner as outlined above for a total of 5 days.

4.10.10 When placing concrete during the period of the year when freezing weather can be expected, the Contractor shall have on the job and ready for immediate use, sufficient materials and equipment for enclosing and protecting the concrete as required for placing concrete at air temperature below 35F.

4.10.11 Concrete that has been frozen or damaged by other causes shall be removed and replaced by the Contractor at his expense.

4.11 HANDLING AND PLACING CONCRETE

4.11.1 GENERAL

4.11.1.1 In preparation for the placing of concrete, sawdust, chips, and other construction debris and extraneous matter shall be removed from the interior of forms. Struts, stays, and braces, serving temporarily to hold the forms in correct shape and alignment, pending the placing of concrete at their locations, shall be removed when the concrete placing has reached an elevation rendering their service unneccessary. These temporary members shall be removed entirely from the forms and not buried in the concrete.

4.11.1.2 Concrete shall be placed so as to avoid segregation of the materials and the displacement of the reinforcement. The use of long troughs, chutes, and pipes for conveying the concrete from the mixer to the forms will be permitted only on written authorization. In case an inferior quality of concrete is produced by the use of such conveyors, the Engineer may order discontinuance of their use and the substitution of a satisfactory method of placing.

4.11.1.3 Open troughs and chutes shall be of metal or metal lined. Where steep slopes are required, the chutes shall be equipped with baffles or be in short lengths that reverse the direction of movement. No chutes, troughs, or pipes made of aluminum shall be used for depositing concrete.

4.11.1.4 Chutes, troughs, and pipes shall be kept clean and free from coatings of hardened concrete. Water used for flushing shall be discharged clear of the structure.

4.11.1.5 When placing operations would involve dropping the concrete more than five feet, it shall be deposited through sheet metal or other approved pipes. As far as practicable, the pipes shall be kept full of concrete during placing and their lower ends shall be kept buried in the newly placed concrete.

After initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the ends of reinforcing bars which project.

4.11.1.6 All concrete, except seal concrete, during and immediately after depositing, shall be thoroughly consolidated. This shall be accomplished by mechanical vibration subject to the following provisions:

4.11.1.6.1 The vibration shall be internal unless special authorization of other methods is given by the Engineer or as provided herein.

4.11.1.6.2 Vibrators shall be of approved type and design. They shall be capable of transmitting vibration to the concrete at frequencies of not less than 4500 impulses per minute.

4.11.1.6.3 The intensity of vibration shall be such as to visibly affect a mass of concrete of 1 inch slump over a radius of at least 18 inches.

4.11.1.6.4 The Contractor shall provide a sufficient number of vibrators to properly compact each batch immediately after it is placed in the forms.

4.11.1.6.5 Vibrators shall be manipulated so as to thoroughly work the concrete around the reinforcement and imbedded fixtures and into the corners and angles of the forms.

(a) 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 any one point to the extent that localized areas of grout are formed.

(b) Application of vibrators shall be at points uniformly spaced and not farther apart than twice the radius over which the vibration is visibly effective.

4.11.1.6.6 Vibration shall not be applied 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.

4.11.1.6.7 Vibration shall be supplemented by such spading as is necessary to insure smooth surfaces and dense concrete along form surfaces and in corners and locations impossible to reach with the vibrators.

4.11.1.6.8 The provisions of this article shall apply to precast piling, concrete cribbing, and other precast members except that, if approved, the manufacturer's methods of vibration may be used.

4.11.1.7 Concrete shall be placed in horizontal layers not more than 12 inches thick except as hereinafter provided. When less than a complete layer is placed in one operation, it shall be terminated in a vertical bulkhead. Each layer shall be placed and consolidated before the preceding batch has taken initial set to prevent injury to the green concrete and to avoid surfaces of separation between the batches.

4.11.1.8 When the placing of concrete is temporarily discontinued, the concrete, after becoming firm enough to retain its form, shall be cleaned of laitance and other objectionable material to a sufficient depth to expose sound concrete. To avoid

visible joints as far as possible upon exposed faces, the top surface of the concrete adjacent to the forms shall be smoothed with a trowel. Where a "feather edge" might be produced at a construction joint, as in the sloped top surface of a wingwall, an inset form shall be used to produce a blocked out portion in the preceding layer which shall produce an edge thickness of not less than 6 inches in the succeeding layer. Work shall not be discontinued within 18 inches of the top of any face, unless provision has been made for a coping less than 18 inches thick, in which case the construction joint may be made at the underside of the coping.

4.11.1.9 Immediately following the discontinuance of placing concrete, accumulations of mortar splashed upon the reinforcing steel and the surfaces of forms shall be removed. Dried mortar chips and dust shall not be puddled into the concrete. If the accumulations are not removed prior to the concrete becoming set, care shall be exercised not to damage or break the concrete-steel bond at and near the surface of the concrete while cleaning reinforcing steel.

4.11.2 CULVERTS

4.11.2.1 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. In this case, suitable provision shall be made for bonding the sidewalls to the culvert base, preferably by means of raised longitudinal keys so constructed as to prevent, as far as possible, the percolation of water through the construction joint.

4.11.2.2 Before concrete is placed in the sidewalls, the culvert footings shall be thoroughly cleaned of shavings, sticks, sawdust, or other extraneous material and the surface carefully chipped and roughened in accordance with the method of bonding construction joints as specified herein.

4.11.2.3 In the construction of box culverts 4 feet or less in height, the sidewalls and top slab may be constructed as a monolith. When this method of construction is used, necessary construction joints shall be vertical and at right angles to the axis of the culvert.

4.11.2.4 In the construction of box culverts more than 4 feet in height the concrete in the walls shall be placed and allowed to set before the top slab is placed. In this case, appropriate keys shall be left in the sidewalls for anchoring the cover slab.

4.11.2.5 If possible, each wingwall shall be constructed as a monolith. Construction joints, where unavoidable, shall be horizontal and so located that no joint will be visible in the exposed face of the wingwall above the ground line.

4.11.3 GIRDERS, SLABS, AND COLUMNS

4.11.3.1 For simple spans, concrete shall preferably be deposited by beginning at the center of the span and working from the center toward the ends. Concrete in girders shall be deposited uniformly for the full length of the girder and brought up evenly in horizontal layers. For continuous spans, where required by design considerations, the concrete placing sequence shall be shown on the plans or in the special provisions.

4.11.3.2 Concrete in girder haunches less than 3 feet in height shall be placed at the same time as that in the girder stem, and the column or abutment tops shall be cut back to form seats for the haunches. Whenever any haunch or fillet has a vertical height of 3 feet or more, the abutment or columns, the haunch, and the girder shall be placed in three successive stages; first, up to the lower side of the haunch; second, to the lower side of the girder; and third, to completion.

4.11.3.3 For haunched continuous girders, the girder stem (including haunch) shall be placed to the top of stem. Where the size of the pour is such that it cannot be made in one continuous operation, vertical construction joints shall preferably be located within the area of contraflexure.

4.11.3.4 Concrete in slab spans shall be placed in one continuous operation for each span unless otherwise provided. All concrete in each pour shall be placed before any concrete in the pour has taken its initial set.

4.11.3.5 The floors and girders of through girder superstructures shall be placed in one continuous operation unless otherwise specified, in which case a special shear anchorage shall be provided to insure monolithic action between girder and floor.

4.11.3.6 Concrete in T-beam or deck girder spans may be placed on one continuous operation or may be placed in two separate operations, each of which shall be continuous; first, to the top of the girder stems, and second, to completion. In the latter case, the bond between stem and slab shall be positive and mechanical, and may be secured by means of suitable shear keys or by artificially roughening the surface of the top of the girder stem. In general, suitable keys may be formed by the use of timber blocks approximately 2 by 4 inches in cross section and having a length of 4 inches less than the width of the girder stem. These key blocks shall be spaced along the girder stems as required, but the spacing shall be not greater than one foot center to center. The blocks shall be beveled and oiled in such manner as to insure their ready removal, and they shall be removed as soon as the concrete has set sufficiently to retain its shape.

4.11.3.7 Concrete in box girders may be placed in two or three separate operations. In either case the bottom slab shall be placed first. Bond between the bottom slab and stem shall be

positive and mechanical. If the webs are placed separately from the top slab, bond between the top slab and webs shall be secured in the same manner as for T-beams. Requirements for shear keys for T-beams shall also apply to box girders, except that keys need not be deeper than the depth to the top of bottom slab reinforcement.

4.11.3.8 Concrete in columns shall be placed in one continuous operation, unless otherwise directed. The concrete shall be allowed to set at least 24 hours before the caps are placed. When friction collars are used to support cap forms, the concrete for columns shall have been poured at least seven days and shall have the minimum compressive strength as specified in Article 4.6.

4.11.3.9 Unless otherwise permitted, no concrete shall be placed in the superstructure until the column forms have been stripped sufficiently to determine the character of the concrete in the columns. The load of the superstructure shall not be allowed to come upon the bents until the test cylinders representing the bents have obtained the minimum compressive strength as specified in Article 4.6, but in no case in less than 7 days.

4.11.4 ARCHES

4.11.4.1 The concrete in arch rings shall be placed in such a manner as to load the centering uniformly.

4.11.4.2 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. When permitted, arch rings may be cast in a single continuous operation.

4.12 PNEUMATIC PLACING

4.12.1 Pneumatic placing of concrete will be permitted only if specified in the special provisions or if authorized. The equipment shall be arranged such that no vibrations result which might damage freshly placed concrete.

4.12.2 Where concrete is conveyed and placed by pneumatic means, the equipment shall be suitable in kind and adequate in capacity for the work. The machine shall be located as close as practicable to the place of deposit. The position of the discharge end of the line shall not be more than 10 feet from the point of deposit. The discharge lines shall be horizontal or incline upwards from the machine.

4.13 PUMPING

4.13.1 Placement of concrete by pumping will be permitted only if specified in the special provisions or if authorized. The equipment shall be so arranged that no vibrations result which might damage freshly placed concrete.

4.13.2 Where concrete is conveyed and placed by mechanically applied pressure, the equipment shall be suitable in kind and adequate in capacity for the work. The use of aluminum pipe as a conveyance for the concrete will not be permitted.

4.13.3 The operation of the pump shall be 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.

4.14 DEPOSITING CONCRETE UNDER WATER

4.14.1 Concrete shall not be deposited in water except on approval, and the method of placing shall be as designated below:

4.14.1.1 Concrete deposited in water shall be Seal concrete. To prevent segregation, it shall be carefully placed in a compact mass, in its final position, by means of a tremie, a bottom dump bucket, 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.

4.14.1.2 For parts of structures under water, when possible, concrete seals shall be placed continuously from start to finish. The surface of the concrete shall be kept as nearly horizontal as practicable. To insure thorough bonding, each succeeding layer of seal shall be placed before the preceding layer has taken initial set.

4.14.1.3 A tremie shall consist of a tube having a diameter of not less than 10 inches, constructed in sections having flanged couplings fitted with gaskets. 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 closed at the start of work so as to prevent water from entering the tube and shall be entirely sealed. The tremie tube shall be kept full to the bottom of the hopper. 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. Aluminum tremies will not be permitted.

4.14.1.4 Depositing of concrete by the drop bottom bucket method shall conform to the following specification. The top of the bucket shall be open. The bottom door shall open freely downward and outward when tripped. The bucket shall be completely filled and slowly lowered to avoid backwash. It shall not be dumped until it rests on the surface upon which the concrete is to be deposited and when discharged, shall be withdrawn slowly until well above the concrete. The slump of concrete shall be maintained between 4 and 8 inches.

4.14.1.5 Dewatering may proceed when the concrete seal is sufficiently hard and strong. 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.

4.15 CONSTRUCTION JOINTS

4.15.1 GENERAL

4.15.1.1 Construction joints shall be made only where located on plans, or shown in the pouring schedule, unless otherwise approved.

4.15.1.2 If not detailed on the plans, or in the case of emergency, construction joints shall be placed as directed. Shear keys or inclined reinforcement shall be used where necessary to transmit shear or bond the two sections together. When shear keys or inclined reinforcement is not provided, the concrete shall be roughened as directed.

4.15.2 BONDING

4.15.2.1 Before depositing new concrete on or against concrete which has hardened, the forms shall be retightened. The surface of the hardened concrete shall be roughened as required, in a manner that will not leave loosened particles of aggregates or damaged concrete at the surface. It shall be thoroughly cleaned of foreign matter and laitance, and saturated with water. To insure an excess of mortar at the juncture of the hardened and the newly deposited concrete, the cleaned and saturated surfaces, including vertical and inclined surfaces, shall first be thoroughly covered with a coating of mortar or neat cement grout against which the new concrete shall be placed before the grout has attained its initial set.

4.15.2.2 The placing of concrete shall be carried continuously from joint to joint. The face edges of all joints which are exposed to view shall be carefully finished true to line and elevation.

4.16 RUBBLE OR CYCLOPEAN CONCRETE

4.16.1 Rubble or cyclopean concrete shall consist of Class B concrete containing large embedded stones. The stone for this class of work may be one-man stone or derrick stone and shall be placed so as to avoid damage to the forms or to the partially set adjacent concrete. Stratified stone shall be placed upon its natural bed. Stone shall be washed and saturated with water before placing.

4.16.2 The total volume of the stone shall not be greater than one-third of the total volume of the portion of the work in which it is placed. For walls or piers greater than 2 feet in thickness, one-man stone shall be used. Each stone shall be surrounded by at least 6 inches of concrete and no stone shall be closer than 1 foot to any top

surface nor any closer than 6 inches to any coping. For walls or piers greater than 4 feet in thickness, derrick stone may be used. Each stone shall be surrounded by at least 1 foot of concrete, and no stone shall be closer than 2 feet to any top surface nor closer than 8 inches to any coping.

4.17 CONCRETE EXPOSED TO SEA WATER

Unless otherwise specifically provided, concrete for structures exposed to sea water shall be Class A concrete as specified in Article 4.6. The clear distance from the face of the concrete to the nearest face of reinforcement steel shall be not less than 4 inches. The concrete shall be mixed for a period of not less than 2 minutes and the water content of the mixture shall be carefully controlled and regulated so as to produce concrete of maximum impermeability. The concrete shall be thoroughly compacted and stone pockets shall be avoided. No construction joints shall be formed between levels of extreme low water and extreme high water as determined by the Engineer. Between these levels sea water shall not come in direct contact with the concrete for a period of not less than 30 days. The original surface, as the concrete comes from the forms, shall be left undisturbed.

4.18 CONCRETE EXPOSED TO ALKALI SOILS OR ALKALI WATER

Where concrete may be exposed to the action of alkaline waters or soils, special care shall be taken to place it in accordance with specifications herein. Wherever possible, placing shall be continuous until completion of the section or until the concrete is at least 18 inches above ground or water level. Alkaline waters or soils shall not be in contact with the concrete during placement and for a period of at least 72 hours thereafter.

4.19 FALSEWORK AND CENTERING

4.19.1 Unless otherwise provided, detailed plans for falsework or centering shall be supplied to the Engineer on request, but in no case shall the Contractor be relieved of responsibility for results obtained by the use of these plans.

4.19.2 For designing falsework and centering, a weight of 150 pounds per cubic foot shall be assumed for green concrete. All falsework shall be designed and constructed to provide the necessary rigidity and to support the loads without appreciable settlement or deformation. The Engineer may require the Contractor to employ screw jacks or approved wedges to take up any settlement in the formwork either before or during the placing of concrete.

4.19.3 Falsework which cannot be founded on a satisfactory footing shall be supported on piling which shall be spaced, driven, and removed in approved manner.

4.19.4 Falsework shall be set to give the finished structure the camber specified or indicated on the plans.

4.19.5 Arch centering shall be constructed according to approved centering plans. Provisions shall be made by means of suitable wedges, sand boxes, or other devices for the gradual lowering of centers to

render the arch self-supporting. When directed, centering shall be placed upon approved jacks in order to take up and correct any slight settlement which may occur after the placing has begun.

4.20 FORMS

4.20.1 Forms shall be of wood, metal, or other approved material and shall be built mortartight and of sufficient rigidity to prevent distortion due to the pressure of the concrete and other loads incident to the construction operations. Forms shall be constructed and maintained so as to prevent warping and the opening of joints due to shrinkage of the lumber.

4.20.2 The forms shall be substantial and unyielding and shall be so designed that the finished concrete will conform to the proper dimensions and contours. The design of the forms shall take into account the effect of vibration of concrete as it is placed.

4.20.3 Forms for exposed surfaces shall preferably be lined with metal, plywood, or other approved material, or may with the Engineer's permission, be made of dressed lumber of uniform thickness. Forms shall be filleted at all sharp corners and shall be given a bevel or draft in the case of all projections such as girders and copings, to insure easy removal.

4.20.4 Metal ties or anchorages within the forms shall be so constructed as to permit their removal to a depth of at least 2 inches from the face without injury to the concrete. In case ordinary wire ties are permitted, all wires, upon removal of the forms, shall be cut back at least 1/4 inch from the face of the concrete with chisels or nippers; for green concrete, nippers are necessary. Fittings for metal ties shall be of such design that, upon their removal, the cavities which are left will be of the smallest possible size. The cavities shall be filled with cement mortar and the surface left sound, smooth, even, and uniform in color.

4.20.5 Forms shall be set and maintained true to the line designated until the concrete is sufficiently hardened. Forms shall remain in place for periods which shall be determined as hereinafter specified. When forms appear to be unsatisfactory in any way, either before or during the placing of concrete, the Engineer will order the work stopped until the defects have been corrected.

4.20.6 The shape, strength, rigidity, watertightness, and surface smoothness of re-used forms shall be maintained at all times. Any warped or bulged lumber must be re-sized before being re-used. Forms which are unsatisfactory in any respect shall not be re-used.

4.20.7 For narrow walls and columns, where the bottom of the form is inaccessible, the lower form boards shall be left loose so that they may be removed for cleaning out extraneous material immediately before placing the concrete.

4.20.8 Forms shall be treated with oil immediately before placing the concrete. Material which will adhere to or discolor the concrete shall not be used.

4.21 REMOVAL OF FALSEWORK AND HOUSING

4.21.1 In the determination of the time for the removal of falsework, forms, and housing, and the discontinuance of heating, consideration shall be given to the location and character of the structure, the weather, and other conditions influencing the setting of the concrete, and the materials used in the mix.

4.21.2 If field operations are not controlled by beam or cylinder tests, the following periods, exclusive of days when the temperature is below 40F, for removal of forms and supports shall be used as a minimum:

Arch Center	14 Days
Centering under Beams	14 Days
Supports under Flat Slabs	14 Days
Floor Slabs	14 Days
Vertical Wall Surfaces	24 Hours
Columns	24 Hours
Sides of Beams	12 Hours
Top Slabs R.C. Box Culverts	14 Days

4.21.3 If high early strength is obtained with Type III cement or by the use of additional cement, these periods may be reduced as directed.

4.21.4 When field operations are controlled by cylinder tests, the removal of forms, supports, and housing, and the discontinuance of heating and curing may begin when the concrete is found to have the required compressive strength, provided further that in no case shall supports be removed in less than 7 days after placing the concrete.

4.21.5 Methods of form removal likely to cause overstressing of the concrete shall not be used. In general, the forms shall be removed from the bottom upwards. Forms and their supports shall not be removed without approval. Supports shall be removed in such a manner as to permit the concrete to uniformly and gradually take the stresses due to its own weight.

4.21.6 In general, arch centering shall be struck and the arch made self-supporting before the railing or coping is placed. This precaution is essential in order to avoid jamming of the expansion joints and variations in alignment. For filled spandrel arches, such portions of the spandrel walls shall be left for construction subsequent to the striking of centers, as may be necessary to avoid jamming of the expansion joints.

4.21.7 Centers shall be gradually and uniformly lowered in such a manner as to avoid injurious stresses in any part of the structure. In arch structures of two or more spans, the sequence of striking centers shall be specified or approved.

4.22 CURING CONCRETE

4.22.1 The concrete in substructures for grade separation structures, superstructures of major structures, roadway slabs of all bridge structures, and railroad underpasses shall be cured with wet cotton mats, wet burlap blankets, or other approved material. Precast concrete products shall be cured in accordance with the requirements of Article 4.33.

4.22.2 White pigmented membrane curing solution may be used for curing concrete in minor drainage structures and the substructures of major structures when surfaces do not require a rubbed finish. When membrane curing is used, the exposed concrete shall be thoroughly sealed immediately after the free water has left the surface. The concrete inside the forms shall be sealed immediately after the forms are removed and necessary finishing has been done. The solution shall be applied in one or two separate applications. If the solution is applied in two increments, the second application shall follow the first application within 30 minutes. 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 one gallon for each 150 square feet of area.

4.22.3 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, a new coat of the solution shall be applied to the affected portions equal in curing value to that above specified.

4.22.4 When curing with cotton mats or burlap blankets is required, the exposed concrete immediately after finishing shall be covered with wet cotton mats or two thicknesses of wet burlap blankets. The cotton mats or burlap blankets shall be kept continuously and thoroughly wet for a period of not less than 5 days after the concrete is placed.

4.23 EXPANSION AND FIXED JOINTS AND BEARINGS

All joints shall be constructed according to details shown on the plans.

4.23.1 OPEN JOINTS

Open joints shall be placed in the locations shown on the plans and 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. Reinforcement shall not extend across an open joint unless so specified on the plans.

4.23.2 FILLED JOINTS

Poured expansion joints shall be constructed similar to open joints. When premolded types are specified, the filler shall be in correct position when the concrete on one side of the joint is placed. When the form is removed, the concrete on the other side shall be placed. Adequate water stops of metal, rubber, or plastic shall be carefully placed as shown on the plans.

4.23.3 PREMOLDED EXPANSION JOINT FILLERS

4.23.3.1 Non-extruding and resilient types shall conform to the Specification for Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction, AASHTO M 153 (ASTM D 1752).

4.23.3.2 Bituminous fiber types shall conform to the Specification for Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction, AASHTO M 213 (ASTM D 1751).

4.23.3.3 Bituminous type filler shall conform to the Specification for Preformed Expansion Joint Filler for Concrete, AASHTO M 33 (ASTM D 994).

4.23.3.4 Preformed Elastomeric Compression Joint Seals shall conform to the Specification for Preformed Elastomeric Compression Joint Seals for Concrete, AASHTO M 220.

4.23.4 STEEL JOINTS

The plates, angles, or other structural shapes shall be accurately shaped, at the shop, to conform to the section of the concrete floor. The fabrication and painting shall conform to the requirements of the specifications covering those items. When called for on the plans or in the special provisions, the material shall be galvanized in lieu of painting. Care shall be taken to insure that the surface in the finished plane is true and free of warping. Positive methods shall be employed in placing the joints to keep them in correct position during the placing of the concrete. The opening at expansion joints shall be that designated on the plans at normal temperature, and care shall be taken to avoid impairment of the clearance in any manner.

4.23.5 WATER STOPS

4.23.5.1 Adequate water stops of metal, rubber, or plastic shall be placed as shown on the plans. Where movement at the joint is provided for, the water stops shall be of a type permitting such movement without injury. They shall be spliced, welded, or soldered, to form continuous watertight joints.

4.23.5.2 Rubber water stops 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 70 percent by volume of neoprene. The tensile strength shall not be less than 2,750 pounds per square inch with an elongation at breaking of 600 percent. The Shore Durometer indication (hardness) shall be between 50 and 60. After 7 days in air at 158(±2)F or after 4 days in oxygen at 158(±2)F and 300 pounds per square inch pressure, the tensile strength shall not be less than 65 percent of the original.

4.23.5.3 The water stops 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 1/32 inch plus or minus.

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.

4.23.5.4 Polyvinylchloride water stops shall be manufactured by the extrusion process from an elastomeric plastic compound, the basic resin of which shall be polyvinylchloride (PVC). The compound shall contain any additional resins, plasticizers, stabilizers, or other materials needed to insure 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.

4.23.5.5 The water stops shall be of the size and shape shown on the plans. They shall be dense, homogeneous, and without holes or other defects.

4.23.5.6 The material shall comply with the following physical requirements when tested under the indicated ASTM test method:

Specific Gravity	ASTM D 792	1.35 Max.
Durometer Hardness	ASTM D 2240	75+5
Tensile Strength	ASTM D 412	1800 psi Min.
Elongation	ASTM D 412	350%
Cold Brittleness	ASTM D 746	-35F
Stiffness in Flexure	ASTM D 747	350 psi Min.

4.23.5.7 The manufacturer shall be responsible for the testing, either in his own or in a recognized commercial laboratory, and shall submit three certified copies of test results.

4.23.6 SHEET COPPER

4.23.6.1 Sheet copper shall conform to the Specifications for Copper Sheet, Strip, Plate, and Rolled Bar, AASHTO M 138 (ASTM B 152).

4.23.6.2 Sheet copper shall meet the Embrittlement Test of Section 10 of M 138.

4.23.7 BEARING DEVICES

4.23.7.1 Bearing plates, rockers, and other expansion devices shall be constructed according to details shown on the plans and in accordance with the applicable Articles of Sections 10, 11, and 25.

4.23.7.2 Roofing used for joint material and bearing pads shall conform to the Specifications for Smooth-Surfaced Asphalt Roll Roofing (Organic Felt), ASTM D 224.

4.24 FINISHING CONCRETE SURFACES

4.24.1 Surface finishes 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
Class 6.	Roadway Surface Finish
Class 7.	Sidewalk Finish

4.24.2 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. If not otherwise specified, exposed surfaces except the tops and bottoms of floor slabs and the interior faces and bottoms of concrete girders shall be given a Class 2, Rubbed Finish.

4.24.3 When metal forms or fiber forms, or lined or plywood forms in good condition are used, the requirement for a Class 2, Rubbed Finish may be waived by the Engineer, except for the following surfaces which shall in all cases be rubbed:

4.24.3.1 ALL STRUCTURES

Retaining walls when visible from the roadway, surfaces of concrete rails, rail posts, rail end posts, rail bases, parapets, and curbs, including the outside face of curbs.

4.24.3.2 HIGHWAY GRADE SEPARATION STRUCTURES AND RAILROAD UNDERPASSES

Surfaces above finished ground of piers, columns, abutments, and retaining walls; the outside vertical surfaces of curbs, slabs and girders, and all exposed surfaces of barrier curbs.

4.24.4 Unless otherwise specified, roadway floors shall be given a Class 6, Roadway Surface Finish, and sidewalks shall be given a Class 7, Sidewalk Finish.

4.25 CLASS 1 - ORDINARY SURFACE FINISH

4.25.1 Immediately following the removal of forms, fins and irregular projections shall be removed from surfaces, except from those which are not to be exposed or are not to be waterproofed. 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 or cement and fine aggregate mixed in the proportions used in the grade of the concrete being finished. Mortar used in pointing shall be not more than 1 hour old. The concrete shall then be rubbed if required or cured as specified under Article 4.22. 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.

4.25.2 The resulting surfaces shall be true and uniform. Repaired surfaces, the appearance of which is not satisfactory, shall be "rubbed" as specified under Class 2, Rubbed Finish.

4.25.3 Exposed surfaces not protected by forms shall be struck off with a straightedge and finished with a wood float to a true and even surface. The use of additional mortar to provide a grout finish will not be permitted.

4.25.4 The tops of caps in the area of the bridge seat shall be finished with a steel trowel or ground to a smooth finish and true slope at the proper elevation.

4.26 CLASS 2 - RUBBED FINISH

4.26.1 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 minimum 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 at this time.

4.26.2 After concrete above the surface being treated has been cast, 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.

4.26.3 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.

4.27 CLASS 3 - TOOLED FINISH

Finish of this character for panels and other like work may be secured by the use of a bushhammer, 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 much longer as may be necessary to prevent the aggregate particles from being "picked" out of the surface. The finished surface shall show a grouping of broken aggregate particles in a matrix of mortar, each aggregate particle being in slight relief.

4.28 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.

4.29 CLASS 5 - WIRE BRUSHED OR SCRUBBED FINISH

As soon as the forms are removed and while the concrete is yet comparatively green, the surface shall be thoroughly and evenly scrubbed with stiff wire or fiber brushes, using a solution of muriatic acid in the proportion of one part acid to four parts water until the cement film or surface is completely removed and the aggregate particles are exposed, leaving an even pebbled texture presenting an appearance grading from that of fine granite to coarse conglomerate, depending upon the size and grading of aggregate used. When the scrubbing has progressed sufficiently to produce the texture desired, the entire surface shall be thoroughly washed with water to which a small amount of ammonia has been added, to remove all traces of acid.

4.30 CLASS 6 - ROADWAY SURFACE FINISH

4.30.1 STRIKING OFF

4.30.1.1 After the concrete is placed and consolidated according to Article 4.11, bridge floors or top slabs of structures serving as finished pavements shall be finished using approved power driven finishing machines. Hand finishing methods may be permitted by the Engineer for short bridges 50 feet or less in length and for irregular areas where the use of a machine would be impractical.

4.30.1.2 When the hand method is permitted, the floors or slabs shall be struckoff with a screed which is parallel to the centerline of the roadway, resting on bulkheads or screed strips cut or set to the required cross section of the roadway. This screed shall be so constructed as to have sufficient strength to retain its shape and the cutting edge shall be adjusted to conform to the profile of the roadway. Screeds shall be of sufficient length to finish the full length of spans 50 feet or less in length. Screed strips or headers shall be accurately set to the specified grades, checked, and adjusted as necessary prior to the final screeding operation. The screed shall be worked back and forth over the surface until the proper profile and cross section is obtained.

4.30.1.3 Floors on bridges over 50 feet in length and on continuous spans shall be placed with lengths of pours as shown on the plans, using power driven finishing machines traveling on rails adjusted to conform to the profile or cross section of the roadway. The machines shall be equipped with oscillating transverse or longitudinal screeds and shall be adjusted to conform to the profile or the required cross section of the roadway. Consolidation by a vibratory action of the finishing machine will not be permitted. The screeds shall have sufficient strength to retain their shape after adjustment. The finishing machine shall go over each area of the bridge floor as many times as it is required to obtain the required profile and cross section. A slight excess of concrete shall be kept in front of the cutting edge of the screed at all times. This excess of concrete shall be carried all the

way to the edge of the pour or form and shall not be worked into the slab but shall be wasted.

4.30.1.4 Excess water, laitance, or foreign materials brought to the surface during the course of the finishing operations shall not be reworked into the slab, but shall be removed immediately upon appearance by means of a squeegee or straightedge drawn from the center of the slab towards either edge.

4.30.1.5 In general, the addition of water to the surface of the concrete to assist in finishing operations will not be permitted. If the application of water to the surface is permitted, it shall be applied as a fog spray by means of approved spray equipment.

4.30.2 STRAIGHTEDGING

After finishing as described above, the entire surface shall be checked by the Contractor with a 10 foot metal straightedge operated parallel to the centerline of the bridge and shall show no deviation in excess of 1/8 inch from the testing edge of the straightedge. Deviations in excess of this requirement shall be corrected before the concrete sets. The checking operation shall progress by overlapping the straightedge at least 1/2 the length of the preceding pass. Major deviations shall be corrected by the strike-off with the straightedge being used to correct minor deviations and as a checking device.

4.30.3 FINAL FINISHING

4.30.3.1 The surface shall be finished by burlap or carpet dragging, brooming, grooving, or by a combination of these methods as required by the contract.

4.30.3.2 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, as the Engineer may approve or direct, carpet or artificial turf of approved type and size may be substituted.

4.30.3.3 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 1/8 of an inch 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

accidental disturbing, during the final brooming, of particles of coarse aggregate embedded near the surface.

4.30.3.4 If the surface is to be grooved, the grooving shall be in a transverse direction using a wire broom or comb having a single row of tines. The grooving may vary from 1/8 inch width at 1/2 inch centers and the groove depth should be approximately 1/8 inch to 3/16 inch. This operation shall be done at such time and in such manner that the desired texure will be achieved while minimizing displacement of the larger aggregate particles. The transverse grooving should terminate approximately one foot from the gutterline at the base of the curb. This area adjacent to the curbs should be given a light broom finish longitudinally. As an alternative, grooving may be achieved using an approved machine designed specifically for grooving concrete pavements.

4.30.4 SURFACE TEST

4.30.4.1 As soon as the surface has set sufficiently to withstand damage when walking on it, and not later than the morning following the placing of the concrete, it shall be straightedged with the 10 foot straightedge and all variations exceeding 1/8 inch shall be plainly marked. These areas shall be corrected by abrasive means until such deviations have been reduced to meet the tolerance specified above.

4.30.4.2 Areas that have been ground shall not be left smooth or polished, but shall have a uniform texture equal in roughness to the surrounding unground concrete.

4.30.5 WORK BRIDGES

The Contractor shall provide suitable and adequate work bridges for proper performance of the work operations as specified and for inspecting the work.

4.31 CLASS 7 - SIDEWALK FINISH

4.31.1 After the concrete 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. An edging tool shall be used on edges and expansion joints. The surface shall not vary more than 1/8 inch under a 10 foot straightedge. The surface shall have a granular or matte texture which will not be slick when wet.

4.31.2 Sidewalk surfaces shall be laid out in blocks with an approved grooving tool as shown on the plans or as directed.

4.32 PNEUMATICALLY APPLIED MORTAR

4.32.1 GENERAL

This section refers to premixed sand and cement pneumatically applied by suitable mechanism and competent operators, and to which mixture the water is added immediately previous to its expulsion from the nozzle.

4.32.2 PROPORTIONS

The proportion of cement to sand shall be based on dry and loose volumes and shall not be less than one to four for encasement of steel members, one to three for concrete repair, nor one to four and a half for special linings.

4.32.3 WATER CONTENT

The water content shall be maintained at a practicable minimum and not in excess of 3 gallons per sack of cement as placed.

4.32.4 MIXING

The cement and sand shall be thoroughly mixed before being charged into the machine. The sand shall contain not less than 3 nor more than 6 percent moisture by weight.

4.32.5 NOZZLE VELOCITY

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.

4.32.6 NOZZLE POSITION

The nozzle shall be held in such a position and at such distance that the stream of flowing material will impinge at approximately right angles to the surface being covered without excessive impact.

4.32.7 REBOUND SAND

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.

4.32.8 FORMS

The forms shall be structurally sufficient and of such design that rebound or accumulated loose sand can freely escape or be readily removed. Shooting strips should be used at corners, edges, and on surfaces where necessary to obtain true lines and proper thickness.

4.32.9 JOINTS

The pneumatically applied mortar at the end of any day's work or similar stopping periods shall be sloped off to a thin edge. Before placing an adjacent section this sloped portion shall be thoroughly cleaned and wetted.

4.32.10 BONDS

Surfaces to which pneumatically applied mortar is to be bonded shall be thoroughly cleaned of dirt, paint, grease, organic matter, and loose particles. Absorptive surfaces shall be wetted before the application of the mortar.

4.32.11 CURING

4.32.11.1 Pneumatically applied mortar shall be so applied, protected, and cured as to prevent its temperature falling below 50F or a loss of moisture from the surface for the periods indicated below:

(a) Where normal portland cement is used, 7 days.

(b) Where high-early strength portland cement is used, 3 days.

4.32.11.2 Pneumatically applied mortar shall be applied only with the permission of the Engineer if the air temperature is 50F or less.

4.32.12 REINFORCEMENT

The reinforcement, when required, shall be adequate from the standpoint of structural requirements and shall consist of mesh or round bars, spaced not less than 2 inches nor more than 4 inches apart either way, and having a diameter not less than that of No. 12 wire. The area of the reinforcement shall be at least 0.2 per cent of the cross-sectional area of the mortar. The reinforcement shall be at least 1/4 inch from the unexposed surface of the mortar and at least 3/4 inch from the exposed surface.

4.33 PRESTRESSED CONCRETE

4.33.1 GENERAL

The construction of prestressed concrete members shall conform to the requirements of preceding articles in this section except as those

requirements are modified or supplemented by the provisions which follow.

4.33.2 SUPERVISION

Unless specifically permitted by the Engineer, the Contractor or Fabricator shall provide a technician skilled in the use of the system of prestressing to be used who shall supervise the work and give the Engineer such assistance as in his judgment may be necessary.

4.33.3 EQUIPMENT

The Contractor or Fabricator shall provide all equipment necessary for the construction and the prestressing. Prestressing shall be done with approved jacking equipment. If hydraulic jacks are used, they shall be equipped with accurately reading pressure gages. The combination of jack and gage shall be calibrated and a graph or table showing the calibration shall be furnished to the Engineer. Should other types of jacks be used, calibrated proving rings or other devices shall be furnished so that the jacking forces may be accurately known.

4.33.4 CONCRETE

4.33.4.1 Concrete shall be controlled, mixed, and handled as specified in other articles of this section unless otherwise specified herein.

4.33.4.2 Concrete shall not be deposited in the forms until the Engineer has inspected the placing of the reinforcement, conduits, anchorages, and prestressing steel and has given his approval thereof.

4.33.4.3 The concrete shall be vibrated internally or externally, or both, as ordered by the Engineer. The vibrating shall be done with care in such a manner as to avoid displacement of reinforcing, conduits, or wires.

4.33.5 ACCELERATED CURING WITH LOW PRESSURE STEAM OR RADIANT HEAT

4.33.5.1 Low pressure steam curing or radiant heat curing shall be done under a suitable enclosure to contain the live steam or the heat. The initial application of the steam or of the heat shall be from two to four hours after the final placement of concrete to allow the initial set of the concrete to take place. If retarders are used, the waiting period before application of the steam or of the radiant heat shall be increased to from four to six hours. 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 C403), and the time limits described above may then be waived.

4.33.5.2 During the waiting period, the temperature within the curing chamber shall not be less than 50F and live steam or radiant heat may be used to maintain the curing chamber at the proper minimum temperature.

4.33.5.3 During the initial application of live steam or of radiant heat, the ambient temperature within the curing enclosure shall increase at an average rate not exceeding 40F per hour until the curing temperature is reached. The maximum curing temperature within the enclosure shall not exceed 160F. The maximum temperature shall be held until the concrete has reached the desired strength. Detensioning shall be accomplished immediately after the steam curing or the heat curing has been discontinued and additional curing is not required after detensioning.

4.33.5.4. CURING WITH LOW PRESSURE STEAM

Application of live steam shall not be directed on the concrete forms as to cause localized high temperatures.

4.33.5.5 CURING WITH RADIANT HEAT

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.

4.33.6 TRANSPORTATION AND STORAGE

4.33.6.1 Precast girders should be transported in an upright position, and points of support and directions of the reactions with respect to the girder should be approximately the same during transportation and storage as when the girder is in its final position. In the event that the Contractor deems it expedient to transport or store precast girders in other than this position, it shall be done at his own risk.

4.33.6.2 Care shall be taken during storage, hoisting, and handling of the precast units to prevent cracking or damage. Units damaged by improper storing or handling shall be replaced by the Contractor at his expense.

4.33.7 PRETENSIONING METHOD

The prestressing elements shall be accurately held in position and stressed by jacks. A record shall be kept of the jacking force and the elongations produced thereby. Several units may be cast in one continuous line and stressed at one time. Sufficient space shall be left between ends of units to permit access for cutting after the concrete has attained the required strength. No bond stress shall be transferred to

the concrete, nor shall end anchors be released, until the concrete has attained a compressive strength as shown by standard cylinders made and cured identically with the members, of at least the minimum strength shown on the plans or in the specifications for such transfer of load. The elements shall be cut or released in such an order that lateral eccentricity of prestress will be a minimum.

4.33.8 POST-TENSIONING METHOD

The tensioning process shall be conducted so that the tension being applied and the elongation may be measured at all times. The friction loss shall be estimated as provided in Division 1, Article 9.16. A record shall be kept of gage pressures and elongations at all times and submitted to the Engineer for his approval. Loads shall not be applied to the concrete until it has attained strength as specified in Article 4.33.7 for pretensioning method.

4.33.9 GROUTING

4.33.9.1 GENERAL

4.33.9.1.1 PURPOSE

The purpose of grouting is to provide permanent protection to the post-tensioning steel and to develop bond between the prestressing steel and the concrete.

4.33.9.1.2 DEFINITION OF TERMS

All terms and symbols are as defined in Guide Specification for Post-Tensioning Materials published by the Prestressed Concrete Institute.

(a) Admixture - Any material added to the grout other than portland cement and water.

(b) Duct - The hole or void provided in the concrete for the post-tensioning tendon.

(c) Grout - A mixture of cement and water with or without admixtures.

(d) Grout opening or vent - An inlet, outlet, or vent in the duct for grout, water, or air.

(e) Post-tensioning - The method of prestressing concrete in which the tendon is stressed after the concrete has reached a specified strength.

(f) Post-tensioning tendons - The complete assembly consisting of anchorage and prestressing steel with sheathing when required. The tendon imparts prestressing forces to the concrete.

(g) Prestressing steel - That element of a post-tensioning tendon which is elongated and anchored to provide the necessary permanent prestressing force.

4.33.9.2 MATERIALS

4.33.9.2.1 PORTLAND CEMENT

Portland cement shall conform to one of the following: Specifications for Portland Cement - AASHTO M 85, Types I, II or III. Cement used for grouting shall be fresh and shall not contain any lumps or other indication of hydration or "pack set."

4.33.9.2.2 WATER

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 prestressing steel.

4.33.9.2.3 ADMIXTURES

(a) Admixtures, if used, shall impart the properties of low water content, good flowability, minimum bleed, and expansion if desired. They shall contain no chemicals in quantities that may have harmful effect on the prestressing steel or cement. Admixtures containing chlorides in excess of 0.5 percent by weight of admixture, assuming 1 lb. of admixture per sack (94 lb. of cement), fluorides, sulphites, and nitrates shall not be used.

(b) Aluminum powder of the proper fineness and quantity or other approved gas evolving material which is well dispersed through the other admixture may be used to obtain 5 to 10 percent unrestrained expansion of the grout.

(c) All admixtures shall be used in accordance with the instructions of the manufacturer.

4.33.9.3 DUCTS

4.33.9.3.1 FORMING

(a) Formed ducts - Ducts formed by sheath left in place shall be a type that will not permit the entrance of cement paste. They shall transfer bond stresses as required and shall retain shape under the weight of the concrete. Metallic sheaths shall be of a ferrous metal, and they may be galvanized.

(b) Cored ducts - Cored ducts shall be formed with no constrictions which would tend to block the passage of grout. All coring materials shall be removed.

4.33.9.3.2 GROUT OPENINGS OR VENTS

All ducts shall have grout openings at both ends. For draped cables, all high points shall have a grout vent except where cable curvature is small, such as in continuous slabs. Grout vents or drain holes shall be provided at low points if the tendon is to be placed, stressed, and grouted in a freezing climate. All grout openings or vents shall include provisions for preventing grout leakage.

4.33.9.3.3 DUCT SIZE

(a) For tendons made up of several wires, bars, or strands, the duct area shall be at least twice the net area of the prestressing steel.

(b) For tendons made up of a single wire, bar, or strand, the duct diameter shall be at least 1/4 in. larger than the nominal diameter of the wire, bar, or strand.

4.33.9.3.4 PLACEMENT OF DUCTS

(a) After placing of ducts, reinforcement and forming is complete, an inspection shall be made to locate possible duct damage. Ducts shall be securely fastened at close enough intervals to avoid displacement during concreting.

(b) All unintentional holes or openings in the duct must be repaired prior to concrete placing.

(c) 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.

4.33.9.4 EQUIPMENT

4.33.9.4.1 The grouting equipment shall include a mixer capable of continuous mechanical mixing which will produce a grout free of lumps and undispersed cement. The equipment shall be able to pump the mixed grout in a manner which will comply with all provisions of this recommended practice.

4.33.9.4.2 Accessory equipment which will provide for accurate solid and liquid measures shall be provided to batch all materials.

4.33.9.4.3 The pump shall be a positive displacement type and be able to produce an outlet pressure of at least 150 psig. 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.

4.33.9.4.4 A pressure gauge having a full scale reading of no greater than 300 psi shall be placed at some point in the grout line between the pump outlet and the duct inlet.

4.33.9.4.5 The grouting equipment shall contain a screen having clear openings of 0.125 in. 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 3/16 in. is satisfactory. This screen shall be easily accessible for inspection and cleaning.

4.33.9.4.6 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.

4.33.9.4.7 Under normal conditions, the grouting equipment shall be capable of continuously grouting the largest tendon on the project in no more than 20 minutes.

4.33.9.5 MIXING OF GROUT

4.33.9.5.1 Water shall be added to the mixer first, followed by portland cement and admixture, or as required by the admixture manufacturer.

4.33.9.5.2 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.

4.33.9.5.3 Water shall not be added to increase grout flowability which has been decreased by delayed use of the grout.

4.33.9.5.4 Proportions of materials shall be based on tests made on the grout before grouting is begun, or may be selected based on prior documented experience with similar materials and equipment and under comparable field conditions (weather, temperature, etc.). The water content shall be the minimum necessary for proper placement, and when Type I or II cement is used shall not exceed a water-cement ratio of 0.45 or approximately 5 gallons of water per sack (94 lb.) of cement.

4.33.9.5.5 The water content required for Type III cement shall be established for a particular brand based on tests.

4.33.9.5.6 The pumpability of the grout may be determined by the Engineer in accordance with the U.S. Corps of Engineers Method CRD-C79. When this method is used, the efflux time of the grout sample immediately after mixing shall not be less than 11 seconds. The flow cone test does not apply to grout which incorporates a thixotropic additive.

4.33.9.6 GROUTING

4.33.9.6.1 PREPARATION OF DUCT

(a) Flushing of metal ducts shall be optional.

(b) Ducts with concrete walls (cored ducts) shall be flushed to ensure that the concrete is thoroughly wetted.

(c) Water used for flushing ducts may contain slack lime (calcium hydroxide) or quicklime (calcium oxide) in the amount of 0.1 lb. per gallon.

4.33.9.6.2 INJECTION OF GROUT

(a) All grout and high point vent openings shall be open when grouting starts. Grout shall be allowed to flow from the first vent after the inlet pipe until any residual flushing water or entrapped air has been removed, at which time the vent should be capped or otherwise closed. Remaining vents shall be closed in sequence in the same manner.

(b) The pumping pressure at the tendon inlet shall not exceed 250 psig.

(c) If the actual grouting pressure exceeds the maximum recommended pumping pressure, grout may be injected at any vent which has been, or is ready to be, capped as long as a one-way flow of grout is maintained. If this procedure is used, then the vent which is to be used for injection shall be fitted with a positive shutoff.

(d) When one-way flow of grout cannot be maintained as outlined in Section (c) above, the grout shall be immediately flushed out of the duct with water.

(e) Grout shall be pumped through the duct and continuously wasted at the outlet pipe until no visible slugs of water or air are ejected and the efflux time of the ejected grout shall not be less than the injected grout. To insure that the tendon remains filled with grout, the outlet and/or inlet shall be closed. Plugs, caps, or valves thus required shall not be removed or opened until the grout has set.

4.33.9.7 TEMPERATURE CONSIDERATIONS

4.33.9.7.1 In temperatures below 32F, ducts shall be kept free of water to avoid damage due to freezing.

4.33.9.7.2 Concrete temperature - The temperature of the concrete shall be 35F or higher from the time of grouting until job cured 2 in. cubes of grout reach a minimum compressive strength of 800 psi.

4.33.9.7.3 Grout temperature - Grout shall not be above 90F during mixing or pumping. If necessary, the mixing water shall be cooled.

4.33.10 PRESTRESSING REINFORCEMENT

4.33.10.1 Prestressing reinforcement shall be high-strength steel wire, high-strength seven-wire strand, or high-strength alloy bars as called for on the plans or in the special provisions.

4.33.10.2 High-strength steel wire shall conform to AASHTO M 204 (ASTM A 421).

4.33.10.3 High-strength seven-wire strand shall conform to the requirements of AASHTO M 203 (ASTM A 416).

4.33.10.4 High-strength alloy bars shall conform to the requirements of AASHTO M 275 (ASTM A 722). Bars with greater minimum ultimate strength, but otherwise produced and tested in accordance with AASHTO M 275 (ASTM A 722), may be used provided they have no properties which make them less satisfactory than the specified material.

4.33.11 TESTING PRESTRESSING REINFORCEMENT AND ANCHORAGES

4.33.11.1 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.

4.33.11.2 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.

4.33.11.3 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.

4.33.11.4 Where the Engineer intends to require nondestructive testing of one or more parts of the structure, special specifications shall be drawn giving the required details of the work.

4.33.11.5 SAMPLING

The vendor shall furnish for testing the following samples selected from each lot. If ordered by the Engineer, the selection of samples shall be made at the manufacturer's plant by the inspector.

4.33.11.5.1 Pretensioning method. - For pretensioned strands, one sample at least 7 feet long shall be furnished in accordance with the requirements of paragraph 9.1 of AASHTO M 203.

4.33.11.5.2 Post-tensioning method. - The following lengths shall be furnished:

(a) For wires requiring heading - 5 feet.

(b) For wires not requiring heading - sufficient length to make up one parallel-lay cable 5 feet long consisting of the same number of wires as the cable to be furnished.

(c) For strand to be furnished with fittings - 5 feet between near ends of fittings.

(d) For bars to be furnished with threaded ends and nuts - 5 feet between threads at ends.

4.33.11.5.3 Anchorage assemblies. - Two anchorage assemblies shall be furnished, complete with distribution plates of each size or type to be used, if anchorage assemblies are not attached to reinforcement samples.

4.33.12 PRECAST SEGMENT MANUFACTURE AND ERECTION

4.33.12.1 MANUFACTURE OF SEGMENTS

4.33.12.1.1 Each segment shall be match-cast with its adjacent segments to ensure proper fit during erection. As the segments are match-cast they must be precisely aligned to achieve the final structure geometry. During the alignment, adjustments to compensate for deflections shall be made.

4.33.12.1.2 All tendon ducts shall be placed during production. The conduit to enclose grouted, post-tensioned tendons shall be mortar tight, made of galvanized, ferrous metal, and may be either rigid with a smooth inner wall, capable of being curved to the proper configuration, or a flexible, interlocking type. Couplers for either type shall also provide a mortar tight connection. Rigid conduit may be fabricated with either welded or interlocking seams. Galvanizing of welded seams for rigid conduit or of conduit couplers will not be required. During placing and finishing of concrete in a segment, inflatable hoses capable of exerting sufficient

pressure on the inside walls shall be placed internally in all conduits and shall extend a minimum of 2 ft. into the conduit in the previously cast segment. Either type of conduit shall be capable of withstanding all forces due to construction operations without damage. Other types of conduit and/or internal protection systems are permitted subject to the approval of the Engineer.

4.33.12.2 ERECTION OF SEGMENTS

4.33.12.2.1 Segments are ususally erected by the cantilever method from each pier without falsework, although temporary supports may be used. With the approval of the Engineer, other systems of erection may be considered.

4.33.12.2.2 Match-cast segments shall be erected using epoxied joints. Pressure shall be provided on the joint by means of post-tensioning. The pressure shall be as uniform as possible with a minimum of 30 psi at any point.

4.33.12.2.3 Deflections of cantilevers shall be measured as erection progresses and compared with computed deflections. Any deviation from the required alignment shall be corrected by either modifying the segment geometry during the casting operation or by inserting stainless steel screen wire shims in the epoxy joints during erection. The maximum thickness of shims at any point shall be 1/16 in. Provision shall be made to permit alignment adjustments of a completed cantilevered portion of the box girder before the midspan splice connecting adjacent cantilevers is constructed.

4.33.12.3 GROUTING

4.33.12.3.1 Grouting of the ducts shall be done in accordance with Article 4.33.9. Under normal conditions, grouting shall be accomplished within 20 calendar days following installation of tendons. For delays beyond 20 days, tendons shall be protected with a water soluble oil or approved equal protective agent.

4.33.12.3.2 Protection of the tendon ducts against splitting from freezing of water in ducts must be provided until cement grout can be used. Use of some other type grout should be considered when erecting in low temperatures.

4.33.13 EPOXY BONDING AGENTS FOR PRECAST SEGMENTAL BOX GIRDERS

4.33.13.1 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 pre-portioned, labeled, ready-to-use containers.

4.33.13.2 Epoxy bonding agents shall be formulated to provide application temperature ranges which will permit erection of match cast segments at substrate temperatures from 40F to 115F. If two surfaces to be bonded have different substrate temperatures, the adhesive applicable at the lower temperature shall be used.

4.33.13.3 If a project would require or benefit from erection at concrete substrate temperatures lower than 40F, the temperature of the concrete to a depth of approximately 3 in. should be elevated to at least 40F to insure effective wetting of the surface by the epoxy compound and adequate curing of the epoxy compound in a reasonable length of time. An artificial environment will have to be provided to accomplish this elevation in temperature and should be created by an enclosure heated by circulating warm air or by radiant heaters. In any event, localized heating shall be avoided and the heat shall be provided in a manner that prevents surface temperatures greater than 110F during the epoxy hardening period. Direct flame heating of concrete surfaces shall be prohibited.

4.33.13.4 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.

4.33.13.5 Surfaces to which the epoxy material is to be applied shall be free from oil, laitance, form release agent, or any other material that would prevent the material from bonding to the concrete surface. All laitance and other contaminants shall be removed by light sand-blasting or by high pressure water blasting with a minimum pressure of 5000 psi. Wet surfaces should be dried before applying epoxy bonding agents. The surface should be at least the equivalent of saturated surface dry (no visible water).

4.33.13.6 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 RPM will be required. Contents of damaged or previously opened containers shall not be used. 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 and shall cover the entire surface with a minimum thickness of 1/16 in. applied on both surfaces or 1/8 in. if applied on one surface. Epoxy should not be placed within 3/8 in. of prestressing ducts to minimize flow into the ducts. A discernible bead line must 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 70 percent of the open time period of the bonding agent.

4.33.13.7 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 minutes after application of the first epoxy material placed and a minimum average temporary prestress of 50 psi over the cross section should be applied with 70 percent of the open time of the epoxy material. At no point of the cross section shall the temporary prestress be less than 30 psi.

4.33.13.8 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.

4.33.13.9 If the jointing is not completed within 70 percent 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.

4.33.13.10 As general instructions cannot cover all situations, specific recommendations and instructions shall be obtained in each case from the Engineer in charge.

4.33.13.11 Epoxy bonding agents shall be tested to determine their workability, gel time, open time, bond and compression strength, shear, and working temperature range. See Article 4.33.15 for test methods and recommended specification limits. The frequency of the tests shall be stated in the Special Provisions of the Contract.

4.33.13.12 The Contractor shall furnish the Engineer samples of the material for testing, and a certification from a reputable independent laboratory indicating that the material has passed the required tests.

4.33.14 INSPECTION OF PRECAST SEGMENTAL BOX GIRDER JOINTING PROCEDURES

In addition to the material acceptance tests, which should be initially performed by a neutral testing laboratory and then checked by the owners' organization, the owners' Inspector should make regular checks of the epoxy jointing procedures. Data such as weather, ambient temperature, concrete surface temperature, adhesive batch number, and the jointing time should be noted. The Inspector should frequently sample and record data such as the observed gel time of the epoxy bonding agent, the surface conditions of the segments being joined, the adequacy of coverage of the adhesive, the amount of material being

squeezed from the joints, and the approximate open time of the epoxy. An approximate determination of the open time can be noted from behavior of lap joint samples spread on small cement-asbestos boards.

4.33.15 EPOXY BONDING AGENT TESTS

4.33.15.1 TEST 1 - SAG FLOW OF MIXED EPOXY BONDING AGENT

This test measures the application workability of the bonding agent.

4.33.15.1.1 Testing Method: ASTM D 2730 for the designated temperature range.

4.33.15.1.2 Specification: Mixed epoxy bonding agent must not sag flow at 1/8 in. minimum thickness at the designated minimum and maximum application temperature range for the class of bonding agents used.

4.33.15.2 TEST 2 - GEL TIME OF MIXED EPOXY BONDING AGENT

Gel time is determined on samples mixed as specified in the testing method. It provides a guide for the period of time the mixed bonding agent remains workable in the mixing container during which it must be applied to the match-cast joint surfaces.

4.33.15.2.1 Testing Method: ASTM D 2471 (except that one quart and one gallon quantities shall be tested).

4.33.15.2.2 Specification: 30 minutes minimum on one quart and one gallon 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).

4.33.15.3 TEST 3 - OPEN TIME OF BONDING AGENT

This test measures workability of the epoxy bonding agent for the erection and post-tensioning operations. As tested here, open time is defined as the minimum allowable period of elapsed time from the application of the mixed epoxy bonding agent to the pre-cast segments until the two segments have been assembled together and temporarily post-tensioned.

4.33.15.3.1 Testing Method: Open time is determined using test specimens as detailed in the Tensile Bending Test (Test 4). 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 minutes 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.

4.33.15.3.2 Specification: The epoxy bonding agent is acceptable for the specified application temperature only when essentially total fracturing of concrete paste and aggregate occurs with no evidence of adhesive failure.

4.33.15.3.3 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 minutes within the temperature range specified for its application.

4.33.15.4 TEST 4 - THREE POINT TENSILE BENDING TEST

This test, performed on a pair of concrete prisms bonded together with epoxy bonding agent, determines the bonding strength between the bonding agent and concrete. The bonded concrete prisms are compared to a reference test beam of concrete 6x6x18 in.

4.33.15.4.1 Testing Method: 6x6x9 in. concrete prisms of 6000 psi compressive strength at 28 days shall be sandblasted on one 6x6 in. side to remove mold release agent, laitance, etc., and submerged in clean water at the lower temperature of the specified application temperature range for 72 hours. Immediately on removing the concrete prisms from the water, the sandblasted surfaces shall be air dried for one hour at the same temperature and 50 percent relative humidity and each shall be coated with approximately a 1/16 in. 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 50 psi. The assembly shall then be wrapped in a damp cloth which is kept wet during the curing period of 24 hours at the lower temperature of the specified application temperature range.

4.33.15.4.2 After 24 hours 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 ASTM C78 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 ASTM C78.

4.33.15.4.3 Specification: The epoxy bonding agent is acceptable if the load on the prisms at failure is greater than 90 percent of the load on the reference test beam at failure.

4.33.15.5 TEST 5 - COMPRESSION STRENGTH OF CURED EPOXY BONDING AGENT

This test measures the compressive strength of the epoxy bonding agent.

4.33.15.5.1 Testing Method: ASTM D695.

4.33.15.5.2 Specification: Compressive strength at 77F shall be 2000 psi minimum after 24 hours cure at the minimum temperature of the designated application temperature range and 6000 psi at 48 hours.

4.33.15.6 TEST 6 - TEMPERATURE DEFLECTION OF EPOXY BONDING AGENT

This test determines the temperature at which an arbitrary deflection occurs under arbitrary testing conditions in the cured epoxy bonding agent. It is a screening test to establish performance of the bonding agent throughout the erection temperature range.

4.33.15.6.1 Testing Method: ASTM D648

4.33.15.6.2 Specification: A minimum deflection temperature of 122F at fiber stress loading of 264 psi is required on test specimens cured 7 days at 77F.

4.33.15.7 TEST 7 - COMPRESSION AND SHEAR STRENGTH OF CURED EPOXY BONDING AGENT

This test is a measure of the compressive strength and shear strength of the epoxy bonding agent compared to the concrete to which it bonds. The "slant cylinder" specimen with the epoxy bonding agent is compared to a reference test cylinder of concrete only.

4.33.15.7.1 Testing Method: A test specimen of concrete is prepared in a standard 6x12 in. cylinder mold to have a height at midpoint of 6 in. and an upper surface with a 30-degree 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 6x12 in. cylinder. If desired, 3x6 in. or 4x8 in. specimens may be used. After the specimens have been moist cured for 14 days, the slant surfaces shall be prepared by light sand-blasting, stoning, or acid etching, then washing and drying the surfaces, and finally coating one of the surfaces with a 10 mil. thickness of the epoxy bonding agent under test. The specimens shall then be pressed together and held in position for 24 hours. The assembly shall then be wrapped in a damp cloth which shall be kept wet during an additional curing period of 24 hours at the minimum temperature of the designated application temperature range. The specimen shall then be tested at 77F following ASTM C39 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 ASTM C39.

4.33.15.7.2 Specification: The epoxy bonding agent is acceptable for the designated application temperature range if the load on the slant cylinder specimen is greater than 90 percent of the load on the companion cylinder.

4.33.16 DECK PANELS

4.33.16.1 The top surface of precast prestressed deck panels, which act compositely with cast-in-place concrete, shall be roughened at the approximate time of initial set by brushing, brooming, or other approved methods to assure bond. This surface shall be kept free of all contaminants, such as oil, which would be detrimental to achieving full bond between the precast panel and the cast-in-place concrete.

4.33.16.2 The panels shall not be supported by or be in contact with intermediate diaphragms.

4.33.16.3 Panels shall be properly handled and stored to prevent breakage. Damage caused by improper handling or storage will be cause for rejection.

4.33.16.4 End panels for skewed structures may be sawed to fit the skew.

4.33.16.5 When panels are erected, 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.

4.34 MEASUREMENT AND PAYMENT

4.34.1 The payment for concrete of the various classes shall include compensation for all equipment, tools, material, falsework, forms, bracing, labor, surface finish, and all other items of expense required to complete the concrete work shown on the plans, with the exception of reinforcement steel. The payment for concrete shall include the cost of joint fillers, metal drains, expansion joints, and miscellaneous metal devices unless they are covered by other items in the contract. The quantity of concrete involved in fillets, scorings, and chamfers 1 square inch or less in cross-sectional area shall be neglected. Payment will be made on the basis of the actual quantity within the neat lines of the structure as shown on the plans or revised by authority of the Engineer, except that deductions shall be made as follows:

4.34.1.1 The volume of structural steel, including steel piling, encased in concrete.

4.34.1.2 The volume of timber piles encased in concrete, assuming the volume to be .8 cubic foot per linear foot of pile.

4.34.1.3 The volume of concrete piles encased in concrete.

4.34.2 No deduction shall be made for the volume of concrete displaced by steel reinforcement, floor drains, or expansion joint material. If a bid is asked on handrailing, that portion of the railing above the top of the roadway curb or above the surface of the sidewalk, as the case may be, shall not be included in the quantity of concrete, but shall be paid for as handrailing. Massive pylons or posts which are to be excepted from handrailing payment shall be so noted on the plans.

4.34.3 Payment for pneumatically applied mortar will be made on the basis of the actual number of square feet placed and accepted. The payment for pneumatically applied mortar shall include compensation for all equipment, tools, materials, labor, and incidentals necessary to complete the work, and shall include metal reinforcement unless otherwise provided.

SECTION 5 - REINFORCING STEEL

5.1 DESCRIPTION

This work shall consist of furnishing and placing reinforcing steel in accordance with these specifications and in conformity with the plans.

5.2 MATERIAL

Reinforcing steel shall conform to the requirements of the following specifications:

5.2.1 Deformed Billet-Steel Bars for Concrete Reinforcement--AASHTO M 31 (ASTM A 615)

5.2.2 Deformed Steel Wire for Concrete Reinforcement--AASHTO M 225 (ASTM A 496)

5.2.3 Welded Steel Wire Fabric for Concrete Reinforcement--AASHTO M 55 (ASTM A 185)

5.2.4 Cold-Drawn Steel Wire for Concrete Reinforcement--AASHTO M 32 (ASTM A 82)

5.2.5 Welded Deformed Steel Wire Fabric for Concrete Reinforcement--AASHTO M 221 (ASTM A 497)

5.2.6 Low Alloy Steel Deformed Bars for Concrete Reinforcement--ASTM A 706

5.3 BAR LISTS AND BENDING DIAGRAMS

Before fabricating material, bar lists and bending diagrams shall be furnished by the Contractor for approval, and no materials shall be fabricated until such lists and bending diagrams 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 incident to 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.

5.4 STORING AND SURFACE CONDITION OF REINFORCEMENT

Steel reinforcement shall be stored above the surface of the ground upon platforms, skids, or other supports and shall be protected as far as practicable from mechanical injury and surface deterioration caused by exposure to conditions producing rust. When placed in the work, reinforcement shall be free from dirt, detrimental rust, loose scale, paint, grease, oil, or other foreign materials. Reinforcement shall be free from injurious defects such as cracks and laminations. Rust, surface seams, surface irregularities, or mill scale will not be cause for rejection, provided the minimum dimensions, cross section area, and tensile properties of a hand wire brushed specimen meets the physical requirements for the size and grade of steel specified.

5.5 FABRICATION

5.5.1 Bar reinforcement shall be bent to the shapes shown on the plans. All bars shall be bent cold, unless otherwise permitted. Bars partially imbedded in concrete shall not be field bent except as shown on the plans or specifically permitted.

5.5.2 Diameters of bends measured on the inside of the bar shall be as shown on the plans. When the diameter of bend is not shown, the minimum bend diameter shall be in accordance with Division I, Article 8.23.

5.5.3 Special fabrication is required for bends exceeding 90° for No. 14 and No. 18 sizes and grades having a specified yield point of 50,000 psi.

5.5.4 Bar reinforcement shall be shipped in standard bundles, tagged and marked in accordance with the Code of Standard Practice of the Concrete Reinforcing Steel Institute.

5.6 PLACING AND FASTENING

5.6.1 Steel reinforcement shall be accurately placed in the positions shown on the plans and firmly held during the placing and setting of concrete. Bars shall be tied at all intersections except where spacing is less than 1 foot in each direction, in which case alternate intersections shall be tied. Welding of cross bars (tack welding) shall not be permitted for assembly of reinforcement unless authorized.

5.6.2 Distances from the forms shall be maintained by means of stays, blocks, ties, hangars, or other approved supports so that the bars do not vary from the position indicated on the plans by more than 1/4 inch. Blocks for holding reinforcement from contact with the forms shall be precast mortar blocks of approved shape and dimensions.

5.6.3 If fabric reinforcement is shipped in rolls, it shall be straightened into flat sheets before being placed.

5.6.4 Bundled bars shall be tied together at not more than 6 feet centers.

5.7 SPLICING OF BARS

All reinforcement shall be furnished in the full lengths indicated on the plans unless otherwise permitted. Splicing of bars, except where shown on the plans, will not be permitted without written approval. Splices shall be staggered as far as possible. Unless otherwise shown on the plans, bars shall be lapped to make the splice in accordance with Division 1, Article 8.33. In lapped splices, the bars shall be placed and wired in such a manner as to maintain the minimum distance to the surface of the concrete shown on the plans. Lapped splices shall not be used for No. 14 and 18 bars except as provided in Division 1, Article 4.5.9.7. Welding of reinforcing steel shall be done only if detailed on the plans or if authorization is made by the Engineer in writing. Welding shall conform to the current specifications, Structural Welding Code, Reinforcing Steel, AWS D1.4 of the American Welding Society and applicable special provisions.

5.8 LAPPING OF MESH OR MATS

Sheets of mesh or bar mat reinforcement shall overlap 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.

5.9 SUBSTITUTIONS

Substitution of different size bars will be permitted only with specific authorization. The substituted bars shall have an area equivalent to the design area, or larger, and shall conform to the requirements of Division 1, Article 8.16.8.4 "Distribution of Flexural Reinforcement."

5.10 MEASUREMENT

5.10.1 Steel reinforcement incorporated in the concrete will be measured in pounds based on the total computed weight for the sizes and lengths of bars, mesh, or mats shown on the plans or authorized.

5.10.2 The weight of mesh will be computed from the theoretical weight of plain wire. If the weight per square foot is given on the plans, that weight shall be used.

5.10.3 The weight of plain bars or bar mat or of deformed bars which do not comply with AASHTO M 31 will be computed from the theoretical weight of plain round or square bars of the same nominal size as shown in the following table:

Size (in.)		1/4	3/8	1/2	5/8	3/4
Weight in pounds per foot	Round Square	0.167	0.376	0.668 0.850	1.043	1.502
Size (in.)		**7/8**	**1**	**1-1/8**	**1-1/4**	**1-1/2**
Weight in pounds per foot	Round Square	2.044	2.670 3.400	4.303	5.313	7.650

5.10.4 The weight of bars which comply with AASHTO M 31 will be calculated as follows:

Bar	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Weight lbs. per lin. ft.	.376	.668.	1.043	1.502	2.044	2.670
Bar	**No. 9**	**No. 10**	**No. 11**	**No. 14**	**No. 18**	
Weight lbs. per lin. ft.	3.400	4.303	5.313	7.65	13.60	

5.10.5 The weight of reinforcement used in railings shall not be included when railings are paid for on a linear foot basis. The weight of reinforcement in precast piles and other items where the reinforcement is included in the contract price for the item shall not be included.

5.10.6 No allowance will 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 steel is used than specified, only the amount specified shall be included.

5.10.7 When laps are made for splices, other than those shown on the plans, for the convenience of the Contractor, the extra steel shall not be included.

5.11 PAYMENT

Payment for reinforcement as determined under measurement shall be made at the contract price per pound. Payment shall include the cost of furnishing, fabricating, and placing of the reinforcing steel.

SECTION 6 - ASHLAR MASONRY

6.1 DESCRIPTION

Ashlar masonry shall consist of first-class cut stone masonry laid in regular courses and shall include all work in which, as distinguished from rubble masonry, the individual stones are dressed or tooled to exact dimensions.

6.2 MATERIALS

6.2.1 ASHLAR STONE

6.2.1.1 Stone for ashlar masonry shall be of the kind specified on the plans or in the contract. The stone shall be tough, dense, sound and durable, resistant to weathering action, reasonably fine grained, uniform in color, and free from seams, cracks, pyrite inclusions, or other structural defects. Preferably, stone shall be from a quarry, the product of which is known to be of satisfactory quality. Stone shall be of such character that it can be brought to such lines and surfaces, whether curved or plane, as may be required. Any stone having defects which have been repaired with cement or other materials shall be rejected.

6.2.1.2 Each bidder shall submit with his bid a 6-inch cubical block of the stone he proposes to furnish and shall designate the quarry from which it is obtained. The quality of the stone furnished shall be at least equal to that of the sample. The sample shall be squared and dressed on three sides; one side shall be smooth-finished, one side fine-finished, and one side shall be given the finish indicated on the plans for exposed surfaces of face stone. The remaining sides shall be left with quarry face.

6.2.1.3 When permitted by the Engineer, bidders may submit bids, accompanied by samples as specified above, on kinds of stone other than that specified.

6.2.1.4 The stone shall be kept free from dirt, oil, or any other injurious material which may prevent the proper adhesion of the mortar or detract from the appearance of the exposed surfaces.

6.2.2 MORTAR

Mortar for laying the stone and pointing shall be composed of one part of portland cement and three parts of sand unless otherwise provided. The sand shall conform to the requirements of Article 4.2.3.

6.3 SIZE OF STONE

The individual stones shall be large and well proportioned. They shall not be less than 12 nor more than 30 inches in thickness. The thickness of courses, if varied, shall diminish regularly from bottom to top of wall. The size of ring stones in arches shall be as shown on the plans.

6.4 SURFACE FINISHES OF STONE

6.4.1 For the purpose of this specification the surface finishes of stone are defined as follows:

6.4.1.1 Smooth-finished: Having a surface in which the variations from the pitch line do not exceed 1/16 inch.

6.4.1.2 Fine-finished: Having a surface in which the variations from the pitch line do not exceed 1/4 inch.

6.4.1.3 Rough-finished: Having a surface in which the variations from the pitch line do not exceed 1/2 inch.

6.4.1.4 Scabbled: Having a surface in which the variations from the pitch line do not exceed 3/4 inch.

6.4.1.5 Rock-faced: Having an irregular projecting face without indications of tool marks. The projections beyond the pitch line shall not exceed 3 inches and no part of the face shall recede back of the pitch line.

6.5 DRESSING STONE

6.5.1 Stones shall be dressed to exact sizes and shapes before being laid and shall be cut to lie on their natural beds with top and bottom truly parallel. Hollow beds will not be permitted. The bottom bed shall be the full size of the stone and no stone shall have an overhanging top. In rock-face construction the face side of any stone shall not present an undercut contour adjacent to its bottom arris giving a top-heavy, unstable appearance when laid.

6.5.2 Beds of face stone shall be fine-finished for a depth of not less than 12 inches.

6.5.3 Vertical joints of face stone shall be fine-finished and full to the square for a depth of not less than 9 inches.

6.5.4 Exposed surfaces of the face stone shall be given the surface finish indicated on the plans, with edges pitched to true lines and exact batter. Chisel drafts 1 1/2 inches wide shall be cut at all exterior corners. Face stone forming the starling or nosing of piers shall be rough-finished unless otherwise specified.

6.5.5 Holes for stone hooks shall not be permitted to show in exposed surfaces.

6.6 STRETCHERS

Stretchers shall have a width of bed of not less than 1 1/2 times their thickness. They shall have a length of bed not less than twice nor more than 3 1/2 times their thickness, and not less than 3 feet.

6.7 HEADERS

Headers shall be placed in each course and shall have a width of not less than 1 1/2 times their thickness. In walls having a thickness of 4 feet or less, the headers shall extend entirely through the wall. In walls of greater thickness, the length of headers shall be not less than 2 1/2 times their thickness when the course is 18 inches or less in height, and not less than 4 feet in courses of greater height. Headers shall bond with the core or backing not less than 12 inches. Headers shall hold in the heart of the wall the same size shown in the face and shall be spaced not further apart than 8 feet center to center. There shall be at least one header to every two stretchers.

6.8 CORES AND BACKING

6.8.1 Cores and backing shall consist either of roughly bedded and jointed headers and stretchers, as specified above, or of Class B or C concrete, as may be specified.

6.8.2 When stone is used for cores or backing, at least 1/2 of the stone shall be of the same size and character as the face stone, and with parallel ends. No course shall be less than 8 inches thick.

6.8.3 Concrete used for cores and backing shall conform to the requirements specified in Section 4.

6.8.4 The headers and stretchers in walls having a thickness of 3 feet or less shall have a width or length equal to the full thickness of the wall. No backing will be allowed.

6.9 MIXING MORTAR

The mortar shall be hand or machine mixed, as may be required by the Engineer. In the preparation of hand-mixed mortar, the sand and cement shall be thoroughly mixed together in a clean, tight mortar box until the mixture is of uniform color, after which clean water shall be added in such quantity as to form a stiff plastic mass. Machine-mixed mortar shall be prepared in an approved mixer and shall be mixed not less than 1 1/2 minutes. Mortar shall be used within 45 minutes after mixing. Retempering of mortar will not be permitted.

6.10 LAYING STONE

6.10.1 GENERAL

Stone masonry shall not be constructed in freezing weather or when the stone contains frost, except by written permission of the Engineer and subject to such conditions as he may require.

6.10.2 FACE STONE

6.10.2.1 Stone shall not be dropped upon, or slid over the wall, nor will hammering, rolling, or turning of stones on the wall be allowed. They shall be carefully set without jarring the stone

already laid and they shall be handled with a lewis or other appliance which will not cause disfigurement.

6.10.2.2 Each stone shall be cleaned and thoroughly saturated with water before being set and the bed which is to receive it shall be cleaned and well moistened. All stones shall be well bedded in freshly made mortar and settled in place with a suitable wooden maul before the setting of the mortar. Whenever possible, the face joints shall be properly pointed before the mortar sets. Joints which cannot be so pointed shall be prepared for pointing by raking them out to a depth of 2 inches before the mortar has set. The face surfaces of stones shall not be smeared with the mortar forced out of the joints or that used in pointing. No pinning up of stones with spalls will be permitted in beds.

6.10.2.3 Joints and beds shall be not less than 3/8 inch nor more than 1/2 inch in thickness and the thickness of the joint or bed shall be uniform throughout.

6.10.2.4 The stones in any one course shall be placed so as to form bonds of not less than 12 inches with the stones of adjoining courses. Headers shall be placed over stretchers and, in general, the headers of each course shall equally divide the spaces between the headers of adjoining courses, but no header shall be placed over a joint and no joint shall be made over a header.

6.10.3 STONE BACKING AND CORES

Stone backing shall be laid in the same manner as specified above for face stone, with headers interlocking with face headers when the thickness of the wall will permit. Backing shall be laid to break joints with the face stone. Stone cores shall be laid in full mortar beds so as to bond not less than 12 inches with face and backing stone and with each other. Bed joints in cores and backing shall not exceed 1 inch and vertical joints shall not exceed 4 inches in thickness.

6.10.4 CONCRETE CORES AND BACKING

The operations involved in the handling and placing of concrete used in cores and backing shall conform to the requirements specified in Section 4. However, the puddling and compacting of concrete adjacent to the ashlar masonry facing shall be done in a manner that will insure the filling of all spaces around the stones and secure full contact and efficient bond with all stone surfaces.

6.11 LEVELING COURSES

6.11.1 Stone cores and backing shall be carried up to the approximate level of the face course before the succeeding course is started.

6.11.2 The construction joints produced in concrete cores or backing by the intermittent placing of concrete shall be located, in general, not less than 6 inches below the top bed of any course of masonry.

6.12 RESETTING

In case any stone is moved or the joint broken, the stone shall be taken up, the mortar thoroughly cleaned from bed and joints, and the stone reset in fresh mortar.

6.13 DOWELS AND CRAMPS

6.13.1 Where required, coping stone, stone in the wings of abutments, and stone in piers shall be secured with wrought-iron cramps or dowels as indicated on the plans.

6.13.2 Dowel holes shall be drilled through each stone before the stone is placed and, after it is in place, such dowel holes shall be extended by drilling into the underlying course not less than 6 inches.

6.13.3 Cramps shall be of the shapes and dimensions shown on the plans or approved by the Engineer. They shall be inset in the stone so as to be flush with the surfaces.

6.13.4 Cramps and dowels shall be set in lead, care being taken to completely fill the surrounding spaces with the molten metal.

6.14 COPINGS

6.14.1 Stones for copings of wall, pier, and abutment bridge seats shall be carefully selected and fully dimensioned stones. On piers, not more than two stones shall be used to make up the entire width of coping. The copings of abutment bridge seats shall be of sufficient width to extend at least 4 inches under the backwall. Each step forming the coping of a wingwall shall be formed by a single stone which shall overlap the stone forming the step immediately below it at least 12 inches.

6.14.2 Tops of copings shall be given a bevel cut at least 2 inches wide, and beds, bevel cuts, and tops shall be fine-finished. The vertical joints shall be smooth-finished and the copings shall be laid with joints not more than 1/4 inch in thickness. The under sides of projecting copings, preferably, shall have a drip bead.

6.14.3 Joints in copings shall be located so as to provide not less than a 12-inch bond with the stones of the under course and so that no joint will come directly under the superstructure masonry plates.

6.15 ARCHES

6.15.1 The number of courses and the depth of voussoirs shall be as shown on the plans. Voussoirs shall be placed in the order indicated, shall be full size throughout, dressed true to template, and shall have bond not less than the thickness of the stone. Beds and joints shall be fine-finished and mortar joints shall not exceed 3/4 inch in thickness. Exposed surfaces of the intrados and arch ring shall be given the surface finish indicated on the plans.

6.15.2 Backing may consist of Class B concrete or of large stones shaped to fit the arch, bonded to the spandrels, and laid in full beds of mortar. The extrados and interior faces of the spandrel walls shall be given a finishing coat of 1:2 1/2 cement mortar which shall be trowelled smooth to receive the waterproofing.

6.15.3 Arch centering, waterproofing, drainage, and filling shall be as specified for concrete arches.

6.16 POINTING

6.16.1 Pointing shall not be done in freezing weather nor when the stone contains frost.

6.16.2 Joints not pointed at the time the stone is laid shall be thoroughly wet with clean water and filled with mortar. The mortar shall be well driven into the joints and finished with an approved pointing tool. The wall shall be kept wet while pointing is being done and in hot or dry weather the pointed masonry shall be protected from the sun and kept wet for a period of at least three days after completion.

6.16.3 After the pointing is completed and the mortar set, the wall shall be thoroughly cleaned and left in a neat and workmanlike condition.

6.17 MEASUREMENT AND PAYMENT

The quantity of stone masonry to be paid for under this item shall be the number of cubic yards measured in the completed work and the limiting dimensions shall not exceed those shown on the plans or fixed by the Engineer. The contract price shall include all labor, tools, materials, and other expense incidental to the satisfactory completion of the work.

SECTION 7 - MORTAR RUBBLE MASONRY

7.1 DESCRIPTION

Mortar rubble masonry, as here specified, shall include the classes commonly known as coursed, random, and random range work and shall consist of roughly squared and dressed stone laid in cement mortar.

7.2 MATERIALS

7.2.1 RUBBLE STONE

7.2.1.1 Stone for mortar rubble or dry rubble masonry shall be of approved quality, sound and durable, and free from segregations, seams, cracks, and other structural defects or imperfections tending to destroy its resistance to the weather. It shall be free from rounded, worn, or weathered surfaces. All weathered stone shall be rejected.

7.2.1.2 The stone shall be kept free from dirt, oil, or any other injurious material which may prevent the proper adhesion of the mortar.

7.2.2 MORTAR

The mortar used shall conform as regards materials, proportions, and mixing to the mortar specified in Article 6.2.2.

7.3 SIZE

7.3.1 SIZE

Individual stones shall have a thickness of not less than 8 inches and a width of not less than 1 1/2 times the thickness. No stones, except headers, shall have a length less than 1 1/2 times their width. Stones shall decrease in thickness from bottom to top of wall.

7.3.2 The size of ring stones for arches shall be as shown on the plans.

7.4 HEADERS

Headers shall hold in the heart of the wall the same size shown in the face and shall extend not less than 12 inches into the core or backing. They shall occupy not less than 1/5 of the face area of the wall and shall be evenly distributed. Headers in walls 2 feet or less in thickness shall extend entirely through the wall.

7.5 SHAPING STONE

7.5.1 The stones shall be roughly squared on joints, beds, and faces. Selected stone, roughly squared and pitched to line, shall be used at all angles and ends of walls. If specified, all corners or angles in exterior surfaces shall be finished with a chisel draft.

7.5.2 All shaping or dressing of stone shall be done before the stone is laid in the wall, and no dressing or hammering which will loosen the stone will be permitted after it is placed.

7.6 LAYING STONE

7.6.1 Stone masonry shall not be constructed in freezing weather or when the stone contains frost, except by written permission of the Engineer and subject to such conditions as he may require.

7.6.2 The masonry shall be laid to line and in courses roughly leveled up. The bottom or foundation courses shall be composed of large, selected stones and all courses shall be laid with bearing beds parallel to the natural bed of the material.

7.6.3 Each stone shall be cleaned and thoroughly saturated with water before being set and the bed which is to receive it shall be clean and well moistened. All stones shall be well bedded in freshly made mortar. The mortar joints shall be full and the stones carefully settled in place before the mortar has set. No spalls will be permitted in the beds. Joints and beds shall have an average thickness of not more than 1 inch.

7.6.4 Whenever possible the face joints shall be properly pointed before the mortar becomes set. Joints which cannot be so pointed shall be prepared for pointing by raking them out to a depth of 2 inches before the mortar has set. The face surfaces of stones shall not be smeared with the mortar forced out of the joints or that used in pointing.

7.6.5 The vertical joints in each course shall break with those in adjoining courses at least 6 inches. In no case shall a vertical joint be so located as to occur directly above or below a header.

7.6.6 In case any stone is moved or the joint broken, the stone shall be taken up, the mortar thoroughly cleaned from bed and joints, and the stone reset in fresh mortar.

7.7 COPINGS, BRIDGE SEATS, AND BACKWALLS

7.7.1 Copings, bridge seats, and backwalls shall be of the material shown on the plans and when not otherwise specified shall be of Class A concrete which shall conform to the requirements of Section 4.

7.7.2 Concrete copings shall be made in sections extending the full width of the wall, not less than 12 inches in thickness, and from 5 to 10 feet long. The sections may be cast in place or precast and set in place in full mortar beds.

7.8 ARCHES

7.8.1 The number of courses and the depth of voussoirs shall be as shown on the plans. Voussoirs shall be placed in the order indicated, shall be full size throughout, and shall have bond not less than their

thickness. Beds shall be roughly pointed to bring them to radial planes. Radial joints shall be in planes parallel to the transverse axis of the arch and, when measured at the intrados, shall not exceed 3/4 inch in thickness. Joints perpendicular to the arch axis shall not exceed 1 inch in thickness when measured at the intrados. The intrados face shall be dressed sufficiently to permit the stone to rest properly upon the centering. Exposed faces of the arch ring shall be rock-faced with edges pitched to true lines.

7.8.2 The work shall be carried up symmetrically about the crown, the stone being laid in full mortar beds, and the joints grouted where necessary. Pinning by the use of stone spalls will not be permitted.

7.8.3 Backing may consist of Class B concrete or of large stones shaped to fit the arch, bonded to the spandrels, and laid in full beds of mortar. The extrados and interior faces of the spandrel walls shall be given a finished coat of 1:2 1/2 cement mortar which shall be trowelled smooth to receive the waterproofing.

7.8.4 Arch centering, waterproofing, draining, and filling shall be as specified for concrete arches.

7.9 POINTING

7.9.1 Pointing shall not be done in freezing weather or when the stone contains frost.

7.9.2 Joints not pointed at the time the stone is laid shall be thoroughly wet with clean water and filled with mortar. The mortar shall be well driven into the joints and finished with an approved pointing tool. The wall shall be kept wet while pointing is being done and in hot or dry weather the pointed masonry shall be protected from the sun and kept wet for a period of at least three days after completion.

7.9.3 After the pointing is completed and the mortar set, the wall shall be thoroughly cleaned and left in a neat and workmanlike condition.

7.10 MEASUREMENT AND PAYMENT

7.10.1 The quantity of stone masonry to be paid for under this item shall be the number of cubic yards measured in the completed work and the limiting dimensions shall not exceed those shown upon the plans or fixed by the Engineer. The contract price shall include all labor, tools, materials, and other items incidental to the satisfactory completion of the work.

7.10.2 Concrete used in connection with rubble masonry shall be paid for as in the case of other concrete construction.

SECTION 8 - DRY RUBBLE MASONRY

8.1 DESCRIPTION

Dry rubble masonry as here specified shall include the classes commonly known as coursed, random, and random range work and shall consist of roughly squared and dressed stone laid without mortar.

8.2 MATERIALS

Stone for mortar rubble or dry rubble masonry shall be of approved quality, sound and durable, and free from segregations, seams, cracks, and other structural defects or imperfections tending to destroy its resistance to the weather. It shall be free from rounded, worn, or weathered surfaces. All weathered stone shall be rejected.

8.3 SIZE OF STONE

The stones shall conform in size to the requirements specified in Section 7.3.

8.4 HEADERS

Headers shall conform to the requirements specified in Section 7.4.

8.5 SHAPING STONE

The stones shall be roughly squared on joints, beds and faces. Selected stone, roughly squared and pitched to line, shall be used at all angles and ends of walls.

8.6 LAYING STONE

8.6.1 The masonry shall be laid to line and in courses roughly leveled up. The bottom or foundation courses shall be composed of large, selected stones and all courses shall be laid with bearing beds parallel to the natural bed of the material. Face joints shall not exceed 1 inch in width.

8.6.2 In laying dry rubble masonry, care shall be taken that each stone takes a firm bearing at not less than three separate points upon the underlying course. Open joints, both front and rear, shall be "chinked" with spalls fitted to take firm bearing upon their top and bottom surfaces, for the purpose of securing firm bearing throughout the length of the stone.

8.6.3 When required by the terms of the contract, the open joints on the rear surfaces of abutments or retaining walls shall be "slushed" thoroughly with mortar to prevent seepage of water through the joints.

8.7 COPINGS, BRIDGE SEATS, AND BACKWALLS

Copings, bridge seats, and backwalls, when used in connection with dry rubble masonry, shall conform to the requirements specified in Section 7.7.

8.8 MEASUREMENT AND PAYMENT

8.8.1 The quantity of stone masonry to be paid for under this item shall be the number of cubic yards measured in the completed work and the limiting dimensions shall not exceed those shown upon the plans or fixed by the Engineer. The contract price shall include all labor, tools, materials, and other expense incidental to the satisfactory completion of the work.

8.8.2 Concrete used in connection with rubble masonry shall be paid for as in the case of other concrete construction.

SECTION 9 - BRICK MASONRY

9.1 DESCRIPTION

Brick masonry shall consist of brick laid in cement mortar and shall include such construction with building brick or ornamental brick as may be specified. Brick pavements are not included under this designation.

9.2 MATERIALS

9.2.1 BRICK

9.2.1.1 Brick for masonry construction shall conform to the Specification for Building Brick (solid masonry units made from clay or shale) AASHTO M 114 (ASTM C 62). The grade of brick to be furnished shall be as specified in the special provisions.

9.2.1.2 The bricks shall have a fine-grained, uniform, and dense structure, free from lumps of lime, laminations, cracks, checks, soluble salts, or other defects which may in any way impair their strength, durability, appearance, or usefulness for the purpose intended. Bricks shall emit a clear, metallic ring when struck with a hammer.

9.2.2 MORTAR

The mortar used shall conform, as regards materials, proportions and mixing, to the mortar specified in Article 6.2.2.

9.3 CONSTRUCTION

9.3.1 The bricks shall be laid in such manner as will thoroughly bond them into the mortar by means of the "shove-joint" method; "buttered" or plastered joints will not be permitted. All brick must be thoroughly saturated with water before being laid. The arrangement of headers and stretchers shall be such as will thoroughly bond the mass and, unless otherwise specified, brick work shall be of alternate headers and stretchers with consecutive courses breaking joints. Other types of bonding, as for ornamental work, shall be as specified on the plans.

9.3.2 All joints shall be completely filled with mortar. They shall not be less than 1/4 inch and not more than 1/2 inch in thickness and the thickness shall be uniform throughout. All joints shall be finished properly as the work progresses and on exposed faces they shall be neatly struck, using the "weather" joint.

9.3.3 No spalls or bats shall be used except for shaping around irregular openings or when unavoidable to finish out a course, in which case full bricks shall be placed at the corners, the bats being placed in the interior of the course.

9.3.4 Piers and walls may be built of solid brick work, or may consist of a brick shell backed with concrete or other suitable material as specified on the plans. None but expert brick layers shall be employed on the work and all details of the construction shall be in accordance with the most approved practice and to the satisfaction of the Engineer.

9.4 COPINGS, BRIDGE SEATS, AND BACKWALLS

9.4.1 The tops of retaining walls, abutment wingwalls and similarly exposed brick work shall be provided, in general, with either a stone or concrete coping. The underside of the coping shall have a batter or drip bead, at least 1 inch beyond the face of the brick work wall. The coping upon an abutment backwall will commonly have no projection beyond its bridge seat face. When concrete is used it shall be of Class A quality. For thin copings, mortar of the same proportions as used for laying the brick may be used to produce precast sections not less than 3 feet nor more than 5 feet in length. No coping shall be less than 4 inches thick.

9.4.2 Copings of piers and abutment bridge seats shall be of Ashlar stone work or of Class A concrete and shall conform to the requirements for "Ashlar Masonry" or "Concrete Masonry" as the plans may indicate. When not shown on the plans, concrete shall be used.

9.5 MEASUREMENT AND PAYMENT

The quantity of brick work to be paid for under this item shall be the number of cubic yards of brick masonry actually placed in the structure in accordance with the plans or as modified by written instructions from the Engineer. This price shall include all labor, materials, and other expenses incidental to the satisfactory completion of the work. Filling material for the interior of the wall, when not of brick, and concrete or mortar copings, shall be paid for on the basis of the number of cubic yards actually placed.

SECTION 10 - STEEL STRUCTURES

FABRICATION

10.1 TYPE OF FABRICATION

These specifications apply to bolted and welded construction.

10.2 QUALITY OF WORKMANSHIP

Workmanship and finish shall be equal to the best general practice in modern bridge shops.

10.3 MATERIALS

10.3.1 STRUCTURAL STEEL

10.3.1.1 GENERAL

Steel shall be furnished according to the following specifications. Unless otherwise specified, structural carbon steel shall be furnished.

10.3.1.2 STRUCTURAL STEEL

10.3.1.2.1 CARBON STEEL

Unless otherwise specified, structural carbon steel for bolted or welded construction shall conform to: Structural Steel, AASHTO M183 (ASTM A36).

10.3.1.2.2 EYEBARS

Steel for eyebars shall be of a weldable grade. These grades include structural steel conforming to:

(a) Structural Steel, AASHTO M183 (ASTM A36).

(b) High-Strength Low-Alloy Structural Steel with 50,000 psi, Minimum Yield Point to 4 in. thick, AASHTO M222 (ASTM A588 with Supplementary Requirement S1 of AASHTO M222 mandatory).

10.3.1.3 HIGH-STRENGTH LOW-ALLOY STRUCTURAL STEEL

High-strength low-alloy structural steel shall conform to:

(a) High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality, AASHTO M223 (ASTM A572).

(b) High-Strength Low-Alloy Structural Steel with 50,000 psi, minimum Yield Point to 4 in. thick, AASHTO M222 (ASTM A588).

10.3.1.4 HIGH-STRENGTH LOW-ALLOY STRUCTURAL STEEL FOR WELDING

High-strength low-alloy structural steel for welding shall conform to:

(a) High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality, Grade 50, AASHTO M 223 (ASTM A572 with Supplementary Requirement S2 of AASHTO M223 mandatory).

(b) High-Strength Low-Alloy Structural Steel with 50,000 psi, minimum Yield Point to 4 in. thick, AASHTO M222 (ASTM A588 with Supplementary Requirement S1 of AASHTO M222 mandatory).

10.3.1.5 HIGH-STRENGTH STRUCTURAL STEEL FOR BOLTED CONSTRUCTION

High-strength structural steel for bolted construction shall conform to:

(a) High-Strength Low-Alloy Columbium-Vanadium Steels of Structural Quality, AASHTO M223 (ASTM A572).

(b) High-Strength Low-Alloy Structural Steel with 50,000 psi Minimum Yield Point to 4 in. thick, AASHTO M222 (ASTM A588).

10.3.1.6 HIGH-YIELD-STRENGTH, QUENCHED, AND TEMPERED ALLOY STEEL PLATE

High-yield-strength, quenched, and tempered alloy steel plate shall conform to:

(a) High-Yield-Strength, Quenched, and Tempered Alloy Steel Plate, suitable for welding, ASTM A514.

(b) High-Strength Alloy Steel Plates, Quenched and Tempered for pressure vessels, ASTM A517.

(c) Quenched and tempered alloy steel structural shapes and seamless mechanical tubing, meeting all of the mechanical and chemical requirements of A514/A517 steel, except that the specified maximum tensile strength may be 140,000 psi for structural shapes and 145,000 psi for seamless mechanical tubing, shall be considered as A514/A517 steel.

10.3.1.7 HIGH-STRENGTH BOLTS

10.3.1.7.1 High-strength bolts for structural steel joints including suitable nuts and plain hardened washers shall conform to either AASHTO M164 (ASTM A325) or AASHTO M253 (ASTM A490). When M164 type 3 bolts are specified they along with suitable nuts and washers shall have an atmospheric corrosion

resistance approximately two times that of carbon steel with copper.

10.3.1.7.2 Bolts and nuts manufactured to AASHTO M164 (ASTM A325) are identified by proper marking as specified on the top of the bolt heads and on one face of the nuts for three different types.

10.3.1.7.3 Bolts manufactured to AASHTO M253 (ASTM A 490) are identified by marking on the top of the head with the symbol A490 and the nuts shall be marked on one face with the legend "2H" or "DH".

10.3.1.7.4 Bolt and nut dimensions shall conform to the dimensions shown in Table 10.3A and to the requirements for Heavy Hexagon Structural Bolts and for Heavy Semi-Finished Hexagon Nuts given in ANSI Standard B18.2.1 and B18.2.2 respectively.

Table 10.3a

Nominal Bolt Size D	Bolt Dimensions in Inches Heavy Hexagon Structural Bolts			Nut Dimensions in Inches Heavy Semi-Finished Hexagon Nuts	
	Width Across Flats F	Height H	Thread Length T	Width Across Flats W	Height H
1/2	7/8	5/16	1	7/8	31/64
5/8	1-1/16	25/64	1-1/4	1-1/16	39/64
3/4	1-1/4	15/32	1-3/8	1-1/4	47/64
7/8	1-7/16	35/64	1-1/2	1-7/16	55/64
1	1-5/8	39/64	1-3/4	1-5/8	63/64
1-1/8	1-13/16	11/16	2	1-13/16	1-7/64
1-1/4	2	25/32	2	2	1-7/32
1-3/8	2-3/16	27/32	2-1/4	2-3/16	1-11/32
1-1/2	2-3/8	15/16	2-1/4	2-3/8	1-15/32

10.3.1.7.5 Circular washers shall be flat and smooth and their nominal dimensions shall conform to the dimensions given in Table 10.3B, except that for lock pin and collar fasteners, flat washers need not be used, unless slotted or oversized holes are specified.

Table 10.3B

WASHER DIMENSIONS[a]

Circular Washers					Square or Rectangular Beveled Washers for American Standard Beams and Channels		
Bolt Size D	Nominal Outside Diameter[b]	Nominal Diameter of Hole	Thickness		Minimum Side Dimensions	Mean Thickness	Slope Of Taper In Thickness
			Min.	Max.			
1/2	1-1/16	17/32	.097	.177	1-3/4	5/16	1:6
5/8	1-5/16	21/32	.122	.177	1-3/4	5/16	1:6
3/4	1-15/32	13/16	.122	.177	1-3/4	5/16	1:6
7/8	1-3/4	15/16	.136	.177	1-3/4	5/16	1:6
1	2	1-1/16	.136	.177	1-3/4	5/16	1:6
1-1/8	2-1/4	1-1/4	.136	.177	2-1/4	5/16	1:6
1-1/4	2-1/2	1-3/8	.136	.177	2-1/4	5/16	1:6
1-3/8	2-3/4	1-1/2	.136	.177	2-1/4	5/16	1:6
1-1/2	3	1-5/8	.136	.177	2-1/4	5/16	1:6
1-3/4	3-3/8	1-7/8	.178[c]	.28[c]	---	---	---
2	3-3/4	2-1/8	.178	.28	---	---	---
Over 2 to 4 Incl.	2D-1/2	D+1/8	.24[d]	.34[d]	---	---	---

[a]Dimensions in inches

[b]May be exceeded by 1/4 inch

[c]3/16 inch nominal

[d]1/4 inch nominal

10.3.1.7.6 Beveled washers for American Standard Beams and Channels or other sloping faces shall be required and shall be square or rectangular, shall taper in thickness, and shall conform to the dimensions given in Table 10.3B.

10.3.1.7.7 Where necessary, washers may be clipped on one side to a point not closer than 7/8 of the bolt diameter from the center of the washer.

10.3.1.7.8 Other fasteners or fastener assemblies which meet the materials, manufacturing, and chemical composition requirements of AASHTO M164 (ASTM A325) or AASHTO M253 (ASTM A490) and which meet the mechanical property requirements of the same specification in full-size tests and which have 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 the previous paragraph, may be used. Such alternate fasteners may differ in other dimensions from those of the specified bolts and nuts. Their installation procedure may differ from those specified in Article 10.17.4 and their inspection may differ from that specified in Article 10.17.5. When a different installation procedure or inspection is used, it shall be detailed in a supplemental specification applying to the alternate fastener and that specification must be approved by the Engineer.

10.3.1.7.9 Subject to the approval of the Engineer, high-strength steel lock-pin and collar fasteners may be used as an alternate for high strength bolts as shown on the plans. The shank and head of the high-strength steel lock-pin and collar fasteners shall meet the requirements of the preceding paragraph. Each fastener shall provide a solid shank body of sufficient diameter to provide tensile and shear strength equivalent to or greater than the bolt specified, 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 a 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.

10.3.1.8 COPPER BEARING STEELS

When copper bearing steel is specified, the steel shall contain not less than 0.2 percent of copper.

10.3.1.9 WELDED STUD SHEAR CONNECTORS

10.3.1.9.1 Shear connector studs shall conform to the requirements of Cold Finished-Carbon Steel Bars and Shafting, AASHTO M 169 (ASTM A108), 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 A109.

10.3.1.9.2 Tensile properties as determined by tests of bar stock after drawing or of finished studs shall conform to the following requirements:

Tensile Strength	(min.)	60,000
Yield Strength*	(min.)	50,000
Elongation	(min.)	20% in 2 inches
Reduction of area	(min.)	50%

10.3.1.9.3 Tensile properties shall be determined in accordance with the applicable sections of 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 4.23.2 of AWS D1.1. If fracture occurs outside of the middle half of the gage length, the test shall be repeated.

10.3.1.9.4 Finished studs shall be of uniform quality and condition, free from injurious laps, fins, seams, cracks, twists, bends, or other injurious defects. Finish shall be as produced by cold drawing, cold rolling, or machining.

10.3.1.9.5 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.

10.3.1.9.6 The Engineer may select, at the Contractor's expense, studs of each type and size used under the contract, as necessary for checking the requirements of this section.

10.3.1.10 UNFILLED TUBULAR STEEL PILES

Unfilled Tubular Steel Piles shall conform to the requirements of Welded and Seamless Steel Pipe Piles ASTM A252, Grade 2, with chemical requirements meeting ASTM A53, Grade B.

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*As determined by a 0.2% offset method.

10.3.2 STEEL FORGINGS AND STEEL SHAFTING

10.3.2.1 STEEL FORGINGS

Steel forgings shall conform to the Specifications for Steel Forgings Carbon and Alloy for General Industrial Use, AASHTO M 102 (ASTM A668), Classes C, D, F, or G.

10.3.2.2 COLD FINISHED CARBON STEEL SHAFTING

Cold finished carbon steel shafting shall conform to the specifications for Cold Finished Carbon Steel Bars and Shafting, AASHTO M 169 (ASTM A 108). Grade 1016-1030, inclusive, shall be furnished unless otherwise specified.

10.3.3 STEEL CASTINGS

10.3.3.1 STEEL CASTINGS FOR HIGHWAY BRIDGES

Steel castings for use in highway bridge components shall conform to Standard Specification for Steel Castings for Highway Bridges, AASHTO M 192 (ASTM A 486) or Mild-to-Medium Strength Carbon-Steel Castings for General Applications AASHTO M 103 (ASTM A 27). The class 70 or grade 70-36 of steel, respectively, shall be used unless otherwise specified.

10.3.3.2 CHROMIUM ALLOY-STEEL CASTINGS

Chromium alloy-steel castings shall conform to the Specification for Corrosion-Resistant Iron-Chromium, Iron-Chromium-Nickel Alloy Castings for General Application, AASHTO M 163 (ASTM A 743). Grade CA 15 shall be furnished unless otherwise specified.

10.3.4 IRON CASTINGS

10.3.4.1 GENERAL

Iron castings shall be gray iron castings conforming to the Specification for Gray Iron Castings, AASHTO M 105 (ASTM A 48), Class No. 30 unless otherwise specified.

10.3.4.2 WORKMANSHIP AND FINISH

10.3.4.2.1 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 value for the service intended.

10.3.4.2.2 Castings shall be boldly filleted at angles and the arrises shall be sharp and perfect.

10.3.4.3 CLEANING

All castings must be sandblasted or otherwise effectively cleaned of scale and sand so as to present a smooth, clean, and uniform surface.

10.3.5 DUCTILE IRON CASTINGS

10.3.5.1 GENERAL

Ductile iron castings shall conform to the Specifications for Ductile Iron Castings, ASTM A 536, Grade 60-40-18 unless otherwise specified. In addition to the specified test coupons, test specimens from parts integral with the castings, such as risers, shall be tested for castings weighing more than 1000 pounds to determine that the required quality is obtained in the castings in the finished condition.

10.3.5.2 WORKMANSHIP AND FINISH

10.3.5.2.1 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 value for the service intended.

10.3.5.2.2 Castings shall be boldly filleted at angles and the arrises shall be sharp and perfect.

10.3.5.3 CLEANING

All castings must be sandblasted or otherwise effectively cleaned of scale and sand so as to present a smooth, clean, and uniform surface.

10.3.6 MALLEABLE CASTINGS

10.3.6.1 GENERAL

Malleable castings shall conform to the Specification for Malleable Iron Castings, ASTM A 47. Grade No. 35018 shall be furnished unless otherwise specified.

10.3.6.2 WORKMANSHIP AND FINISH

10.3.6.2.1 Malleable 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 value for the service intended.

10.3.6.2.2 The castings shall be boldly filleted at angles and the arrises shall be sharp and perfect. The surfaces shall have a workmanlike finish.

10.3.6.3 CLEANING

All castings must be sandblasted or otherwise effectively cleaned of scale and sand so as to present a smooth, clean, and uniform surface.

10.3.7 BRONZE CASTINGS AND COPPER-ALLOY PLATES

10.3.7.1 BRONZE CASTINGS

Bronze castings shall conform to Standard Specifications for Bronze Castings for Bridges and Turntables, AASHTO M 107 (ASTM B 22) Alloys 913 or 911.

10.3.7.2 COPPER-ALLOY PLATES

Copper-alloy plates shall conform to Standard Specifications for Rolled Copper-Alloy Bearing and Expansion Plates and Sheets for Bridge and other Structural Uses, AASHTO M 108 (ASTM B 100).

10.3.8 SHEET LEAD

Sheet lead shall conform to the requirements for Common Desilverized Lead of the Specification for Pig Lead, ASTM B 29.

10.3.9 SHEET ZINC

Sheet zinc shall conform to the requirements for Type II of the Specifications for Rolled Zinc, ASTM B 69.

10.3.10 GALVANIZING

When galvanizing is shown on the plans or specified in the special provisions, ferrous metal products shall be galvanized in accordance with the Specifications for Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates, Bars, and Strip, AASHTO M 111 (ASTM A 123).

10.3.11 CANVAS AND RED LEAD FOR BEDDING MASONRY PLATES

These pads shall be formed on the bridge seat bearing area by swabbing the area with red lead paint, then placing upon it 3 layers of 12 to 14 ounce duck. Each layer shall be thoroughly swabbed on its top surface with red lead paint. The red lead paint shall conform to the specifications for paint for metals, Article 14.2.

10.3.12 PREFORMED FABRIC PADS

The preformed fabric pads shall be composed of multiple layers of 8-ounce cotton duck impregnated and bound 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 10,000 pounds per square inch without detrimental reduction in thickness or extrusion.

10.4 STORAGE OF MATERIALS

Structural material, either plain or fabricated, shall be stored at the bridge shop above the ground upon 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.

10.5 STRAIGHTENING MATERIAL AND CURVING ROLLED BEAMS AND WELDED GIRDERS

10.5.1 STRAIGHTENING MATERIAL

Rolled material, before being laid off or worked, must be straight. If straightening is necessary, it shall be done by methods that will not injure the metal. Heat straightening of AASHTO M 244 (ASTM A514) or ASTM A517 steel shall be done only under rigidly controlled procedures, each application subject to the approval of the Engineer. In no case shall the maximum temperature of the steel exceed 1125F. Sharp kinks and bends shall be cause for rejection of the material.

10.5.2 CURVING ROLLED BEAMS AND WELDED GIRDERS

10.5.2.1 MATERIALS

Steels that are manufactured to a specified minimum yield point greater than 50,000 psi shall not be heat curved.

10.5.2.2 TYPE OF HEATING

10.5.2.2.1 Beams and girders may be curved by either continuous or V-type heating as approved by the Engineer. For the continuous method, a strip along the edge of the top and bottom flange shall be heated simultaneously; the strip shall be of sufficient width and temperature to obtain the required curvature. For the V-type heating, the top and bottom flanges shall be heated in truncated triangular or wedge-shaped areas having their base along the flange edge and spaced at regular intervals along each flange; the spacing and temperature shall be as required to obtain the required curvature, and heating shall progress along the top and bottom flange at approximately the same rate.

10.5.2.2.2 For the V-type heating, the apex of the truncated triangular area applied to the inside flange surface shall terminate just before the juncture of the web and the flange is reached.* When the radius of curvature is 1000 feet or more, the apex of the truncated triangular heating pattern

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*To avoid unnecessary web distortion, special care shall be taken when heating the inside flange surfaces (the surfaces that intersect the web) so that heat is not applied directly to the web.

applied to the outside flange surface shall extend to the juncture of the flange and web. When the radius of curvature is less than 1000 feet, the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend past the web for a distance equal to 1/8 of the flange or 3 inches, whichever is less. The truncated triangular pattern shall have an included angle of approximately 15 to 30 degrees, but the base of the triangle shall not exceed 10 inches. Variations in the patterns prescribed above may be made with the approval of the Engineer.

10.5.2.2.3 For both types of heating, the flange edges to be heated are those that will be on the inside of the horizontal curve after cooling. Heating both inside and outside flange surfaces is only mandatory when the flange thickness is 1 1/4 inches or greater, in which case, the two surfaces shall be heated concurrently. The maximum temperature shall be prescribed below.

10.5.2.3 TEMPERATURE

The heat-curving operation shall be conducted in such a manner that the temperature of the steel does not exceed 1150F as measured by temperature indicating crayons or other suitable means. The girder shall not be artificially cooled until after naturally cooling to 600F, the method of artificial cooling is subject to the approval of the Engineer.

10.5.2.4 POSITION FOR HEATING

10.5.2.4.1 The girder may be heat-curved with the web in either a vertical or a horizontal position. When curved in the vertical position, the girder must be braced or supported in such a manner that the tendency of the girder to deflect laterally during the heat-curving process will not cause the girder to overturn.

10.5.2.4.2 When curved in the horizontal position, the girder must be supported near its ends and at intermediate points, if required, to obtain a uniform curvature; the bending stress in the flanges due to the dead weight of the girder must not exceed the usual allowable design stress. When the girder is positioned horizontally for heating, intermediate safety catch blocks must be maintained at the midlength of the girder within 2 inches of the flanges at all times during the heating process to guard against a sudden sag due to plastic flange buckling.

10.5.2.5 SEQUENCE OF OPERATIONS

The girder shall be heat-curved in the fabrication shop before it is painted. The heat curving operation may be conducted either before or after all the required welding of transverse intermediate stiffeners is completed. However, unless provisions are

made for girder shrinkage, connection plates and bearing stiffeners shall be located and attached after heat curving. If longitudinal stiffeners are required, they shall be heat-curved or oxygen-cut separately and then welded to the curved girder. When cover plates are to be attached to rolled beams, they may be attached before heat curving if the total thickness of one flange and cover plate is less than 2 1/2 inches and the radius of curvature is greater than 1000 feet. For other rolled beams with cover plates, the beams must be heat-curved before the cover plates are attached; cover plates must be either heat curved or oxygen-cut separately and then welded to the curved beam.

10.5.2.6 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.

10.5.2.7 MEASUREMENT OF CURVATURE AND CAMBER

Horizontal curvature and vertical camber shall not be measured for final acceptance before 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 by measuring off-sets from a string line or wire attached to both flanges or by using other suitable means; camber shall be checked by adequate means.

10.6 FINISH

Portions of the work exposed to view shall be finished neatly. Shearing, flame cutting, and chipping shall be done carefully and accurately.

10.7 BOLT HOLES

10.7.1 HOLES FOR HIGH-STRENGTH BOLTS AND UNFINISHED BOLTS**

10.7.1.1 All holes for bolts shall be either punched or drilled. Material forming parts of a member composed of not more than five

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*The heat-curving process may tend to change the vertical camber present before heating. This effect shall be most pronounced when the top and bottom flanges are of unequal widths on a given transverse cross section.

**See Article 10.16 for bolts included in designation "Unfinished Bolts."

thicknesses of metal may be punched 1/16 inch larger than the nominal diameter of the bolts whenever the thickness of the material is not greater than 3/4 inch for structural steel, 5/8 inch for high-strength steel or 1/2 inch for quenched and tempered alloy steel, unless subpunching and reaming is required under Article 10.10.

10.7.1.2 When there are more than five thicknesses or when any of the main material is thicker than 3/4 inch for structural steel, 5/8 inch for high-strength steel, or 1/2 inch for quenched and tempered alloy steel, all holes shall either be subdrilled or drilled full size.

10.7.1.3 When required under Article 10.10, all holes shall be either subpunched or subdrilled (subdrilled if thickness limitation governs) 3/16 inch smaller and, after assembling, reamed 1/16 inch larger or drilled full size to 1/16 inch larger than the nominal diameter of the bolts.

10.7.1.4 When permitted by Division 1, Article 10.32, enlarged or slotted holes are allowed with high-strength bolts.

10.7.2 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 3/16 inch smaller than the nominal diameter of the bolt and reamed, 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 on the plans or in the special provisions.

10.8 PUNCHED HOLES

The diameter of the die shall not exceed the diameter of the punch by more than 1/16 inch. 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. Poor matching of holes will be cause for rejection.

10.9 REAMED OR DRILLED HOLES

Reamed or drilled holes shall be cylindrical, perpendicular to the member, and shall comply with the requirements of Article 10.7 as to size. Where practicable, reamers shall be directed by mechanical means. Burrs on the outside surfaces shall be removed. Poor matching of holes will be cause for rejection. Reaming and drilling shall be done with twist drills. If required by the Engineer, assembled parts shall be taken apart for removal of burrs caused by drilling. 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.

10.10 PREPARATION OF FIELD CONNECTIONS

10.10.1 SUBPUNCHING AND REAMING OF FIELD CONNECTIONS

10.10.1.1 Unless otherwise specified in the special provisions or on the plans, holes in all field connections and field splices of main members of trusses, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames shall be subpunched (or subdrilled if subdrilling is required according to Article 10.7) and subsequently reamed while assembled or to a steel template, as required by Article 10.14. All holes for floor beam and stringer field end connections shall be subpunched and reamed to a steel template or reamed while assembled. 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.

10.10.1.2 For any connection, in lieu of subpunching and reaming or subdrilling and reaming, the fabricator may, at his option, drill holes full size with all thicknesses or material assembled in proper position.

10.10.1.3 If additional subpunching and reaming is required, it shall be specified in the special provisions or on the plans.

10.10.2 NUMERICALLY-CONTROLLED DRILLED FIELD CONNECTIONS

10.10.2.1 GENERAL

10.10.2.1.1 Alternately, for any connection or splice designated in Article 10.10.1, in lieu of sub-sized 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 sub-sized and reamed holes by means of suitable numerically-controlled (N/C) drilling or punching equipment subject to the specific provisions contained in this article. Full size punched holes shall meet the requirements of Article 10.7.

10.10.2.1.2 If N/C drilling or punching equipment is used, the Engineer, unless otherwise stated in the special provisions or on the plans, may require the Contractor, by means of check assemblies to demonstrate that this drilling or punching procedure consistently produces holes and connections meeting the requirements of Articles 10.12 and 10.14.

10.10.2.1.3 The Contractor shall submit to the Engineer for approval a detailed outline of the procedures that he

proposes to follow in accomplishing the work from initial drilling or punching through check assembly, if required, to include the specific members of the structure that may be N/C drilled or punched, the sizes of the holes, the location of common index and other reference points, composition of check assemblies, and all other pertinent information.

10.10.2.2 HOLES

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.

10.11 ACCURACY OF PUNCHED AND DRILLED HOLES

All holes punched full size, subpunched, or subdrilled shall be so accurately punched that after assembling (before any reaming is done) a cylindrical pin 1/8 inch 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 75 percent of the contiguous holes in the same plane. If the requirement is not fulfilled, the badly punched pieces will be rejected. If any hole will not pass a pin 3/16 inch smaller in diameter than the nominal size of the punched hole, this will be cause for rejection.

10.12 ACCURACY OF REAMED AND DRILLED HOLES

10.12.1 When holes are reamed or drilled, 85 percent of the holes in any contiguous group shall, after reaming or drilling, show no offset greater than 1/32 inch between adjacent thicknesses of metal.

10.12.2 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.

10.13 FITTING FOR BOLTING

10.13.1 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.

10.13.2 The drifting done during assembling shall be only such as to bring the parts into position and not sufficient to enlarge the holes or distort the metal.

10.14 SHOP ASSEMBLING

10.14.1 The field connections of main members of trusses, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames shall be assembled in the shop with milled ends of compression members in full bearing, and then shall have their sub-size holes reamed to specified size while the connections are assembled. Assembly shall be Full Truss or Girder Assembly unless Progressive Truss or Girder Assembly, Full Chord Assembly, Progressive Chord Assembly, or Special Complete Structure Assembly is specified in the special provisions or on the plans.

10.14.2 Check Assemblies with Numerically-Controlled Drilled Field Connections shall be in accordance with the provisions of Article 10.14.4.6.

10.14.3 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.

10.14.4 A camber diagram shall be furnished 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 (1/4 points minimum, 1/10 points maximum) in case of continuous beam and girders or rigid frames. When the shop assembly is Full Truss or Girder Assembly or Special Complete Structure Assembly, the camber diagram shall show the camber measured in assembly. When any of the other methods of shop assembly is used, the camber diagram shall show calculated camber.

10.14.4.1 FULL TRUSS OR GIRDER ASSEMBLY

Full Truss or Girder Assembly shall consist of assembling all members of each truss, arch rib, bent, tower face, continuous beam line, plate girder, or rigid frame at one time.

10.14.4.2 PROGRESSIVE TRUSS OR GIRDER ASSEMBLY

Progressive Girder Assembly shall consist of assembling initially for each arch rib, continuous beam line, or plate girder at least three contiguous shop sections. Progressive Truss Assembly shall consist of assembling initially for each truss, bent, tower face, or rigid frame, all members in at least three contiguous panels but not less than the number of panels associated with three contiguous chord lengths. Successive assemblies shall consist of not less than two sections or panels of the previous assembly (repositioned if necessary and adequately pinned to assure accurate alignment) plus one or more sections or panels added at the advancing end. In the case of structures longer than 150 feet, each assembly shall be not less than 150 feet 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.

Assemblies consisting of less than three shop sections or panels shall require approval of the Engineer.

10.14.4.3 FULL CHORD ASSEMBLY

10.14.4.3.1 Full Chord Assembly shall consist of assembling, with geometric angles at the joints, the full length of each chord of each truss or open spandrel arch, or each leg of each bent or tower, then reaming their field connection holes while the members are assembled and reaming the web member connections to steel templates set at geometric (not cambered) angular relation to the chord lines.

10.14.4.3.2 Field connection holes in web members shall be reamed to steel templates. At least one end of each web member shall be milled or shall be scribed normal to the

longitudinal axis of the member and the templates at both ends of the member shall be accurately located from one of the milled ends or scribed lines.

10.14.4.4 PROGRESSIVE CHORD ASSEMBLY

Progressive Chord Assembly shall consist of assembling contiguous chord members in the manner specified for Full Chord Assembly and in the number and length specified for Progressive Truss or Girder Assembly.

10.14.4.5 SPECIAL COMPLETE STRUCTURE ASSEMBLY

Special Complete Structure Assembly shall consist of assembling the entire structure, including the floor system. (This procedure is ordinarily needed only for complicated structures such as those having curved girders, or extreme skew in combination with severe grade or camber.)

10.14.4.6 CHECK ASSEMBLIES WITH NUMERICALLY-CONTROLLED DRILLED FIELD CONNECTIONS

10.14.4.6.1 A check assembly shall be required for each major structural type of each project, unless otherwise designated on the plans or in the special provisions, 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. Such special points could be the portals of skewed trusses, etc.

10.14.4.6.2 Use of either geometric angles (giving theoretically zero secondary stresses under dead-load conditions after erection) or cambered angles (giving theoretically zero secondary stresses under no-load conditions) should be designated on the plans or in the special provisions.

10.14.4.6.3 The check assemblies shall preferably be the first such sections of each major structural type to be fabricated.

10.14.4.6.4 No match-marking and no shop assemblies other than the check assemblies shall be required.

10.14.4.6.5 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 contracting authority.

10.15 MATCH-MARKING

Connecting parts assembled in the shop for the purpose of reaming holes in field connections shall be match-marked, and a diagram showing such marks shall be furnished to the Engineer.

10.16 BOLTS AND BOLTED CONNECTIONS

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 10.17.

10.16.1 GENERAL

Bolts shall be unfinished, turned, or ribbed bolts conforming to the requirements for Grade A Bolts of Specification for Low-Carbon Steel Externally and Internally Threaded Standard Fasteners, ASTM A 307. Bolted connections shall be used only as indicated by the plans or special provisions. Bolts shall have single self-locking nuts or double nuts unless otherwise shown on the plans or in the special provisions. 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.

10.16.2 UNFINISHED BOLTS

Unfinished bolts shall be furnished unless other types are specified.

10.16.3 TURNED BOLTS

The surface of the body of turned bolts shall meet the ANSI roughness rating value of 125. 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.

10.16.4 RIBBED BOLTS

10.16.4.1 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 5/64 inch greater than the nominal diameter specified for the bolts.

10.16.4.2 Ribbed bolts shall be furnished with round heads conforming to ANSI B 18.5 unless otherwise 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 mash down enough 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.

10.17 CONNECTIONS USING HIGH STRENGTH BOLTS

10.17.1 GENERAL

This article covers the assembly of structural joints using AASHTO M164 (ASTM A325) or AASHTO M253 (ASTM A490) high-strength bolts, or equivalent fasteners, tightened to a high tension. The bolts are used in holes conforming to the requirements of Articles 10.7, 10.8, and 10.9.

10.17.2 BOLTS, NUTS, AND WASHERS

Bolts, nuts, and washers shall conform to the requirements of Article 10.3.1.7.

10.17.3 BOLTED PARTS

10.17.3.1 The slope of surfaces of bolted parts in contact with the bolt head and nut shall not exceed 1:20 with respect to a plane normal to the bolt axis. Bolted parts shall fit solidly together when assembled and shall not be separated by gaskets or any other interposed compressible material.

10.17.3.2 When assembled, all joint surfaces, including those adjacent to the bolt head, nuts, or washers, shall be free of scale, except tight mill scale, and shall also be free of burrs, dirt, and other foreign material that would prevent solid seating of the parts. Paint is permitted unconditionally in bearing-type connections.

10.17.3.3 In friction-type connections the Class, as defined below, indicating the condition of the contact surfaces shall be specified on the plans. Where no Class is specified all joint surfaces shall be free of scale, except tight mill scale and shall not have a vinyl wash.

(a) Classes A, B, and C (uncoated): Contact surfaces shall be free of oil, paint, lacquer, or other coatings.

(b) Class D (hot dip galvanized and roughened): Contact surfaces shall be lightly scored by wire brushing or blasting after galvanizing and prior to assembly. The wire brushing treatment shall be a light application of manual or power brushing that marks or scores the surface but removes relatively little of the zinc coating. The blasting treatment shall be a light "brush-off" treatment which will produce a dull gray appearance. However, neither treatment should be severe enough to produce any break or discontinuity in the zinc surface.

(c) Classes E and F (blast-cleaned, zinc rich paint): Contact surfaces shall be coated with organic or inorganic zinc rich paint as defined in the Steel Structures Painting Council System SSPC 12.00.

(d) Classes G and H (blast-cleaned, metallized zinc or aluminum): Contact surfaces shall be coated in accordance with AWS C2.2. Recommended Practice for Metallizing with Aluminum and Zinc for Protection of Iron and Steel, except that subsequent sealing treatments, described in Section IV therein, shall not be used.

(e) Class I (vinyl wash): Contact surfaces shall be coated in accordance with the provisions of the Steel Structures Painting Council Pretreatment Specifications SSPC PT3.

10.17.3.4 AASHTO M164 (ASTM A325) Type 2 and AASHTO M253 (ASTM A490) bolts shall not be galvanized nor shall they be used to connect galvanized material.

10.17.4 INSTALLATION

10.17.4.1 BOLT TENSION

10.17.4.1.1 Each fastener shall be tightened to provide, when all fasteners in the joint are tight, at least the minimum bolt tension shown in Table 10.17A for the size of fastener used.

Table 10.17A

BOLT TENSION

Bolt Size in inches	Minimum Bolt Tension[a] in pounds	
	AASHTO M 164 (ASTM A 325) Bolts	AASHTO M 253 (ASTM A 490) Bolts
1/2	12,050	14,900
5/8	19,200	23,700
3/4	28,400	35,100
7/8	39,250	48,500
1	51,500	63,600
1-1/8	56,450	80,100
1-1/4	71,700	101,800
1-3/8	85,450	121,300
1-1/2	104,000	147,500

[a]Equal to 70 percent of specified minimum tensile strength of bolts.

10.17.4.1.2 Threaded bolts shall be tightened by one of the methods described in Articles 10.17.4.3, 10.17.4.4, and 10.17.4.5. If required because of bolt entering and wrench operational clearances, tightening by the selected procedure may be done by turning the bolt while the nut is prevented

from rotating. Impact wrenches, if used, shall be of adequate capacity and sufficiently supplied with air to perform the required tightening of each bolt in approximately ten seconds.

10.17.4.1.3 AASHTO M253 (ASTM A490) and galvanized AASHTO M164 (ASTM A325) bolts shall not be reused. Other AASHTO M164 (ASTM A325) bolts may be reused, but not more than once, if approved by the Engineer. Retightening previously tightened bolts which may have been loosened by the tightening of adjacent bolts shall not be considered as a reuse.

10.17.4.2 WASHERS

10.17.4.2.1 All fasteners shall have a hardened washer under the element (nut or bolt head) turned in tightening except that AASHTO M164 (ASTM A325) bolts installed by the turn of the nut method in holes which are not oversize or slotted may have the washer omitted. Hardened washers shall be used under both the head and nut regardless of the element turned in the case of AASHTO M253 (ASTM A490) bolts if the material against which it bears has a specified yield strength less than 40 ksi.

10.17.4.2.2 Where an outer face of the bolted parts has a slope more than 1:20 with respect to a plane normal to the bolt axis, a smooth beveled washer shall be used to compensate for the lack of parallelism.

10.17.4.3 TURN-OF-NUT TIGHTENING

When the turn-of-nut method is used to provide the bolt tension specified in Article 10.17.4.1, there shall first be enough bolts brought to a "snug tight" condition to insure that the parts of the joint are brought into full contact with each other. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench. Following this initial operation, bolts shall be placed in any remaining holes in the connection and brought to snug tightness. All bolts in the joint shall then be tightened additionally by the applicable amount of nut rotation specified in Table 10.17B with tightening progressing systematically from the most rigid part of the joint to its free edges. During this operation there shall be no rotation of the part not turned by the wrench.

Table 10.17B

NUT ROTATION[a] FROM SNUG TIGHT CONDITION

Bolt Length measured from underside of head to extreme end of point	Disposition of Outer Faces of Bolted Parts		
	Both faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1:20 (bevel washer not used)	Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used)
Up to and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters[b]	2/3 turn	5/6 turn	1 turn

[a]Nut rotation is relative to bolt, regardless of the element (nut or bolt) being turned. For bolts installed by 1/2 turn and less, the tolerance should be plus or minus 30°; for bolts installed by 2/3 turn and more, the tolerance should be plus or minus 45°.

[b]No research work has been performed by the Research Council on Riveted and Bolted Structural Joints to establish the turn-of-nut procedure when bolt lengths exceed 12 diameters. Therefore, the required rotation must be determined by actual tests in a suitable tension device simulating the actual conditions.

10.17.4.4 LOCK-PIN AND COLLAR FASTENERS

The installation of lock-pin and collar fasteners shall be by methods and procedures approved by the Engineer.

10.17.4.5 TIGHTENING BY USE OF A LOAD INDICATING FASTENER SYSTEM

Tightening by this means is permitted provided it can be demonstrated by an accurate direct measurement procedure that the bolt has been tightened in accordance with Table 10.17A. Tightening shall be by methods and procedures approved by the Engineer.

10.17.5 INSPECTION

10.17.5.1 The Engineer shall determine that the requirements of Articles 10.17.5.2 and 10.17.5.3 following, are met in the work.

10.17.5.2 The Engineer shall observe the installation and tightening of bolts to determine that the selected tightening procedure is properly used and shall determine that all bolts are tightened and in the case of direct tension indicator method that the correct indication of tension has been achieved. Bolts may reach tensions substantially above the value given in Table 10.17A, but this shall not be cause for rejection.

10.17.5.3 The following inspection shall be used unless a more extensive or different inspection procedure is specified.

(a) Either the Engineer or the Contractor in the presence of the Engineer, at the Engineer's option, shall use an inspection wrench which may be a torque wrench.

(b) Three bolts of the same grade, size,* and condition as those under inspection shall be placed individually in a calibration device capable of indicating bolt tension at least once each working day. There shall be a washer under the part turned in tightening each bolt if washers are so used on the structure. If no washer is used the material abutting the part turned shall be of the same specification as that used on the structure.

(c) Each bolt specified in Paragraph (b) shall be tightened in the calibration device by any convenient means to an initial condition equal to 15 percent of the required tension and then the minimum tension specified for its size in Article 10.17.4.1. The inspecting wrench then

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*Length may be any length representative of bolts used in the structure.

shall be applied to the tightened bolt and the torque necessary to turn the nut or head 5 degrees (approximately 1 inch at 12 inch radius) in tightening direction shall be determined. The average torque measured in the tests of three bolts shall be taken as the job inspecting torque to be used in the manner specified in Paragraph (b).

(d) Bolts, represented by the sample prescribed in Paragraph (b), which have been tightened in the structure shall be inspected by applying, in the tightening direction, the inspecting wrench and its job inspecting torque to 10 percent of the bolts, but not less than two bolts, selected at random in each connection. If no nut or bolt head is turned by this application of the job inspecting torque, the connection shall be accepted as properly tightened. If any nut or bolt head is turned by the application of the job inspecting torque, this torque shall be applied to all bolts in the connection, and all bolts whose nut or head is turned by the job inspecting torque shall be tightened and reinspected, or alternatively, the Fabricator or Erector, at his option, may retighten all of the bolts in the connection and then resubmit the connection for the specified inspection.

10.17.5.4 . The procedures for inspecting and testing the lock-pin procedures and collar fasteners and their installation to assure that the required preload tension is provided shall be as approved by the Engineer.

10.18 PLATE CUT EDGES

10.18.1 EDGE PLANNING

Sheared edges of plate more than 5/8-inch in thickness and carrying calculated stress shall be planed, milled, ground, or thermal cut to a depth of 1/4-inch.

10.18.2 FLAME CUTTING

Flame cutting of structural steel shall conform to the requirements of Article 3.22 of the AASHTO Standard Specifications for Welding of Structural Steel Highway Bridges, 1981.

10.18.3 VISUAL INSPECTION AND REPAIR OF PLATE CUT EDGES

Visual inspection and repair of plate cut edges shall be in accordance with Article 3.2.3 of the AASHTO Standard Specifications for Welding of Structural Steel Highway Bridges, 1981.

10.18.4 RE-ENTRANT CORNERS

Re-entrant corners shall be filleted to a minimum radius of 3/4-inch before cutting.

10.19 WELDS

Welding of steel structures when authorized in accordance with the provisions of Division 1, shall conform to the AWS Structural Welding Code AWS D1.1-80, as modified by the AASHTO Standard Specifications for Welding of Structural Steel Highway Bridges, 1981, and subsequent AASHTO Interim Specifications Bridges.

10.20 FACING OF BEARING SURFACES

The surface finish of bearing and 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:

Steel slabs	ANSI	2,000
Heavy plates in contact in shoes to be welded	ANSI	1,000
Milled ends of compression members, milled or ground ends of stiffeners and fillers	ANSI	500
Bridge rollers and rockers	ANSI	250
Pins and pin holes	ANSI	125
Sliding bearings	ANSI	125

10.21 ABUTTING JOINTS

Abutting joints 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 3/8 inch.

10.22 FABRICATION OF MEMBERS

10.22.1 Unless otherwise shown on the plans, 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.

10.22.2 Fabricated members shall be true to line and free from twists, bends, and open joints.

10.23 BENT PLATES

Unwelded, cold-bent, load-carrying, rolled-steel plates shall conform to the following:

10.23.1 They shall be so taken from the stock plates that the bend line will be at right angles to the direction of rolling, except that cold-bent ribs for orthotropic-deck bridges may be bent in the direction of rolling if permitted by the Engineer.

10.23.2 BENDING

10.23.2.1 Bending shall be such that no cracking of the plate occurs. Minimum bend radii, measured to the concave face of the metal, are shown in the following table:

THICKNESS IN INCHES

	Up to 1/2	Over 1/2 to 1	Over 1 to 1-1/2	Over 1-1/2 to 2-1/2	Over 2-1/2 to 4
All grades of structural steel in this specification	2t	2-1/2t	3t	3 1/2t	4t

10.23.2.2 Allowance for springback of AASHTO M244 (ASTM A514) and ASTM A517 steels should be about 3 times that for structural carbon steel. For break press forming, the lower die span should be at least 16 times the plate thickness. Multiple hits are advisable.

10.23.2.3 If a shorter radius is essential, the plates shall be bent hot at a temperature not greater than 1200F, except for AASHTO M244 (ASTM A514) and ASTM A517 steels. If AASHTO M244 (ASTM A514) or ASTM A517 steel plates to be bent are heated to a

temperature greater than 1125F, they must be requenched and tempered in accordance with the producing mill's practice. Hot bent plates shall conform to the requirements of 10.23.1 above.

10.23.3 Before bending, the corners of the plate shall be rounded to a radius of 1/16 inch throughout the portion of the plate at which the bending is to occur.

10.24 FIT OF STIFFENERS

End stiffeners of 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 shown on the plans or specified) on the flanges to which they transmit load or from which they receive load. Stiffeners not intended to support concentrated loads shall, unless shown or specified otherwise, fit sufficiently tight to exclude water after being painted.

10.25 EYEBARS

10.25.1 Pin holes may be flame cut at least two inches 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 the pin 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. 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 1/16 inch to a foot.

10.25.2 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.

10.26 ANNEALING AND STRESS RELIEVING

10.26.1 Structural members which are indicated in the contract 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 E44. 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 100F at any one time.

10.26.2 Members of AASHTO M244 (ASTM A514) or ASTM A517 steels shall not be annealed or normalized and shall be stress relieved only with the approval of the Engineer.

10.26.3 A record of each furnace charge shall identify the pieces in the charge and show the temperatures and schedule actually used.

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 AASHTO M244 (ASTM A514) or ASTM A517 steels shall not exceed 1125F.

10.26.4 Members, such as bridge shoes, pedestals, or other parts which are built up by welding sections of plate together shall be stress relieved in accordance with the procedure of paragraph 4.4 of AWS D1.1 when required by the plans, specifications, or special provisions governing the contract.

10.27 PINS AND ROLLERS

10.27.1 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 9 inches in diameter shall be forged rollers and annealed. Pins and rollers 9 inches or less in diameter may be either forged and annealed or cold-finished carbon-steel shafting.

10.27.2 In pins larger than 9 inches in diameter, a hole not less than 2 inches 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 injury by too rapid cooling, and before being annealed.

10.28 BORING PIN HOLES

10.28.1 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.

10.28.2 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 1/32 inch. Boring of holes in built-up members shall be done after the riveting is completed.

10.29 PIN CLEARANCES

The diameter of the pin hole shall not exceed that of the pin by more than 1/50 inch for pins 5 inches or less in diameter, or by 1/32 inch for larger pins.

10.30 THREADS FOR BOLTS AND PINS

Threads for all bolts and pins for structural steel construction shall conform to the Unified Standard Series UNC - ANSI B1.1, Class 2A for external threads and Class 2B for internal threads, except that pin ends having a diameter of 1-3/8 inches or more shall be threaded 6 threads to the inch.

10.31 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. The term "mill" means any rolling mill or foundry where material for the work is to be manufactured. No material shall be manufactured, or work done in the shop, before the Engineer has been so notified.

10.32 FACILITIES FOR INSPECTION

The Contractor shall furnish facilities for the inspection of material and workmanship in the mill and shop, and the Inspectors shall be allowed free access to the necessary parts of the works.

10.33 INSPECTOR'S AUTHORITY

Inspectors shall have the authority to reject any material or work which does not meet the requirements of these specifications. In case of dispute the Contractor may appeal to the Engineer, whose decision shall be final.

10.34 WORKING DRAWINGS AND IDENTIFICATION OF STEEL DURING FABRICATION

10.34.1 WORKING DRAWINGS

10.34.1.1 The Contractor shall submit copies of the detailed shop drawings to the Engineer for approval. Any work done prior to the approval of these plans shall be at the Contractor's risk. When material must be ordered in advance, specific approval of such an action shall be obtained by the Contractor prior to placing the order. 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.

10.34.1.2 The Contractor shall expressly understand that the Engineer's approval of the working drawings submitted by the Contractor covers the requirements for "strength and detail," and that the Engineer assumes no responsibility for errors in dimensions.

10.34.2 IDENTIFICATION OF STEELS DURING FABRICATION

10.34.2.1 IDENTIFICATION BY CONTRACTOR

10.34.2.1.1 The Engineer shall be furnished with complete certified mill test reports showing chemical analysis and the physical tests for each heat of steel, for all members unless excepted by the Engineer. Each piece of steel to be fabricated shall be properly identified for the Engineer.

10.34.2.1.2 Shop drawings shall specifically identify each piece that is to be made of steel which is to be other than AASHTO M 183 (ASTM A36) steel. Pieces made of different grades of steel shall not be given the same assembling or

erecting mark, even though they are of identical dimensions and detail.

10.34.2.1.3 The Contractor's system of assembly-marking individual pieces, required to be made of steel other than AASHTO M 183 (ASTM A36) steel, and the issuance of cutting instructions to the shop (generally by cross-referencing of the assembly-marks shown on the shop drawings with the corresponding item covered on the mill purchase order) shall be such as to maintain identity of the mill test report number.

10.34.2.1.4 The Contractor may furnish from stock, material that he can identify by heat number and mill test report.

10.34.2.1.5 Any excess material placed in stock for later use shall be marked with the mill test report number and shall be marked with its AASHTO M 160 (ASTM A6) specification identification color code (see Table 10.34) if any, when separated from the full-size piece furnished by the supplier.

10.34.2.2 IDENTIFICATION OF STEELS DURING FABRICATION

10.34.2.2.1 During fabrication, up to the point of assembling members, each piece of steel, other than AASHTO M 183 (ASTM A36) steel, shall show clearly and legibly its specification identification color code shown in Table 10.34.

10.34.2.2.2 Individually marked pieces of steel which are used in furnished size, or reduced from furnished size only by end or edge trim, that does not disturb the heat number or color code or leave any usable piece, may be used without further color coding provided that the heat number or color code remains legible.

10.34.2.2.3 Pieces of steel, other than AASHTO M 183 (ASTM A 36) steel, which are to be cut to smaller size pieces shall, before cutting, be legibly marked with the AASHTO M 160 (ASTM A 36) specification identification color code.

10.34.2.2.4 Individual pieces of steel, other than AASHTO M 183 (ASTM A36) steel, which are furnished in tagged lifts or bundles shall be marked with the AASHTO M 160 (ASTM A6) specification identification color code immediately upon being removed from the bundle or lift.

10.34.2.2.5 Pieces of steel, other than AASHTO M 183 (ASTM A 36) steel, which prior to assembling into members, will be subject to fabricating operations such as blast cleaning, galvanizing, heating for forming, or painting which might obliterate paint color code marking, shall be marked for grade by steel die stamping or by a substantial tag firmly attached.

10.34.2.2.6 The following identification color code shall be used to identify material required to meet the individual specifications listed in Table 10.34.

Table 10.34

IDENTIFICATION COLOR CODES

AASHTO M244 (ASTM A 514)	Red
ASTM A517	Red and Blue
AASHTO M223 (ASTM A 572)	Grade 50 Green and Yellow
AASHTO M222 (ASTM A 588)	Blue and Yellow

Other steels, except AASHTO M 183 (ASTM A36) steel, not covered above, nor included in the AASHTO M 160 (ASTM A6) Specification, shall have an individual color code which shall be established and on record for the Engineer.

10.34.2.3 CERTIFICATION OF IDENTIFICATION

Upon request, the Contractor shall furnish an affidavit certifying that throughout the fabrication operation he has maintained the identification of steel in accordance with this specification.

10.35 WEIGHING OF MEMBERS

In case it is specified that any part of the material is to be paid for by actual weight, finished work shall be weighed in the presence of the Inspector, if practicable. In such case, the Contractor shall supply satisfactory scales and shall perform all work involved in handling and weighing the various parts.

10.36 FULL SIZE TESTS

When full size tests of fabricated structural members or eyebars are required by the contract, the plans or specifications shall state the number and nature of the tests, the results to be attained and the measurements of strength, deformation, or other performance that are to be made. The Contractor shall provide suitable facilities, material, supervision, and labor necessary for making and recording the tests. The members tested in accordance with the contract shall be paid for in accordance with Article 10.54. The cost of testing including equipment, handling, supervision, labor, and incidentals for making the tests shall be included in the contract price for the fabrication or fabrication and erection of structural steel, whichever is the applicable item in the contract, unless otherwise specified.

10.37 MARKING AND SHIPPING

10.37.1 Each member shall be painted or marked with an erection mark for identification and an erection diagram shall be furnished with erection marks shown thereon.

10.37.2 The Contractor shall furnish to the Engineer as many copies of material orders, shipping statements, and erection diagrams as the Engineer may direct. The weights of the individual members shall be shown on the statements. Members weighing more than 3 tons shall have the weights 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 excessively stressed, deformed, or otherwise damaged.

10.37.3 Bolts of one length and diameter and loose nuts or washers of each size shall be packed separately. 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 300 lbs. A list and description of the contained material shall be plainly marked on the outside of each shipping container.

10.38 PAINTING

Unless otherwise shown on the plans or specified, all iron and steel surfaces shall be cleaned and painted in accordance with Section 14 "PAINTING METAL STRUCTURES."

ERECTION

10.39 ORTHOTROPIC-DECK SUPERSTRUCTURES

10.39.1 PROTECTION OF DECK PLATE AFTER SANDBLASTING

If sandblasting to a white metal, or an equivalent method, is used to prepare the deck plate to receive a wearing surface, a protective coating shall be applied to the plate immediately after cleaning.

10.39.2 DIMENSIONAL TOLERANCE LIMITS

10.39.2.1 Dimensional tolerance limits for orthotropic-deck bridge members shall be applied to each completed but unloaded member and shall be as specified in the AWS Specification referred to in Article 10.19 except as superseded hereinafter. The deviation from detailed flatness, straightness, or curvature at any point shall be the perpendicular distance from that point to a templet edge having the detailed straightness or curvature and which is in contact with the element at two other points. The term element as used herein, refers to individual panels, stiffeners, flanges, or other pieces. The templet 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 templet 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.

10.39.2.1.1 FLATNESS OF PANELS

(a) The term panel as used in this article means a clear area of steel plate surface bounded by stiffeners, webs, flanges, or plate edges and not further subdivided by any such elements. The provisions of this article apply to all panels in the bridge; for plates stiffened on one side only such as orthotropic-deck plates or flanges of box girders, this includes the total clear width on the side without stiffeners as well as the panels between stiffeners on the side with stiffeners.

(b) The maximum deviation from detailed flatness or curvature of a panel shall not exceed the greater of:

$$3/16 \text{ inch or } \frac{D}{144\sqrt{T}} \text{ inch} \qquad (10\text{-}1)$$

where

D = the least dimension in inches along the boundary of the panel.

T = the minimum thickness in inches of the plate comprising the panel.

10.39.2.1.2 STRAIGHTNESS OF LONGITUDINAL STIFFENERS SUBJECT TO CALCULATED COMPRESSIVE STRESS, INCLUDING ORTHOTROPIC-DECK RIBS

The maximum deviation from detailed straightness or curvature in any direction perpendicular to its length of a longitudinal stiffener subject to calculated compressive stress, including each orthotropic-deck rib, shall not exceed:

$$\frac{L}{480} \qquad (10\text{-}2)$$

where

L = the length of the stiffener or rib between cross members, webs, or flanges, in inches.

10.39.2.1.3 STRAIGHTNESS OF TRANSVERSE WEB STIFFENERS AND OTHER STIFFENERS NOT SUBJECT TO CALCULATED COMPRESSIVE STRESS

The maximum deviation 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:

$$\frac{L}{240} \qquad (10\text{-}3)$$

where

L = the length of the stiffener between cross members, webs, or flanges, in inches.

10.40 ERECTION OF STRUCTURE

10.40.1 If the substructure and superstructure are built under separate contracts, the Department will provide the masonry, constructed to correct lines and elevations and properly finished, and will establish the lines and elevations required for setting the steel.

10.40.2 The Contractor shall erect the metalwork, remove the temporary construction, and do all work required to complete the bridge or bridges as covered by the agreement, including the removal of the old structure or structures, if stipulated, all in accordance with the plans and these specifications.

10.41 PLANS

If the fabrication and erection of the superstructure are done under separate contracts, the Department will furnish detail plans for the bridge or bridges to be erected, including shop details, camber diagrams, erection diagrams, list of field bolts, and copy of shipping statements showing a list of parts and their weights.

10.42 PLANT

The Contractor shall provide the falsework and all tools, machinery, and appliances, including drift pins and fitting-up bolts, necessary for the expeditious handling of the work.

10.43 DELIVERY OF MATERIALS

If the contract is for erection only, the Contractor shall receive the materials entering into the finished structure free of charge at the place designated and loaded or unloaded as specified. The Contractor shall unload promptly upon delivery any material delivered to the place designated, which he is required to unload. Otherwise, he shall be responsible for demurrage charges.

10.44 HANDLING AND STORING MATERIALS

Material to be stored 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 injury from deflection. If the contract is for erection only, the Contractor shall check the material turned over to him against the shipping lists and report promptly in writing any shortage or injury discovered. He shall be responsible for the loss of any material while in his care, or for any damage caused to it after being received by him.

10.45 FALSEWORK

The falsework shall be properly designed and substantially constructed and maintained for the loads which will come upon it. The Contractor, if required, shall prepare and submit to the Engineer for approval, plans for falsework or for changes in an existing structure necessary for maintaining traffic. Approval of the Contractor's plans shall not be considered as relieving the Contractor of any responsibility.

10.46 METHODS AND EQUIPMENT

Before starting the work of erection, the Contractor shall inform the Engineer fully as to the method of erection he proposes to follow, and the amount and character of equipment he proposes to use, which shall be subject to the approval of the Engineer. The approval of the Engineer shall not be considered as relieving the Contractor of the responsibility for the safety of his method or equipment or from carrying out the work in full accordance with the plans and specifications. No work shall be done until such approval by the Engineer has been obtained.

10.47 BEARINGS AND ANCHORAGES

10.47.1 Bridge bearings shall be set level, in exact position, and must have full and even bearing on the masonry.

10.47.2 Elastomeric bearing pads, if used, shall set directly on the concrete masonry.

10.47.3 Cast iron or steel, or rolled steel bearings shall be bedded on the masonry with alternate layers of red lead and canvas, or a single thickness of sheet lead or preformed fabric bearing pad.

10.47.4 The Contractor shall drill holes for anchor bolts and set them in portland cement grout, or pre-set them as shown on the plans or as specified.

10.47.5 Location of anchors and setting of rockers or rollers shall take into account any variation from mean temperature 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 rockers and rollers shall set vertical and anchor bolts at expansion bearings will center their slots. Care shall be taken that full and free movement of the superstructure at the movable bearings is not restricted by improper setting or adjustment of bearings or anchor bolt and nuts.

10.47.6 Bridge bearings shall not be placed on masonry bearing areas which are irregular or improperly formed.

10.48 STRAIGHTENING BENT MATERIAL AND CAMBERING

10.48.1 STRAIGHTENING BENT MATERIAL

10.48.1.1 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 injury. Distorted members shall be straightened by mechanical means or, if approved by the Engineer, by the careful procedures planned and supervised application of a limited amount of localized heat, except that heat straightening of AASHTO M244 (ASTM A514) or ASTM A517 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 of the AASHTO M244 (ASTM A514) or ASTM A517 steels exceed 1125F, nor shall the temperature exceed 950F at the weld metal or within 6 inches of weld metal. Heat shall not be applied directly on weld metal. In all other steels, the temperature of the heated area shall not exceed 1200F (a dull red) as controlled by temperature indicating crayons, liquids, or bimetal thermometers.

10.48.1.2 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.

10.48.1.3 Following the straightening of a bend or buckle, the surface of the metal shall be carefully inspected for evidence of fracture.

10.48.2 CAMBERING

Correction of errors in camber in welded beams and girders of AASHTO M244 (ASTM A514) or ASTM A517 material shall be done only under rigidly controlled procedures, each application subject to approval of the Engineer.

10.49 ASSEMBLING STEEL

10.49.1 The parts shall be accurately assembled as shown on the plans 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. Unless erected by the cantilever method, truss spans shall be erected on blocking so as to give the trusses proper camber. The blocking shall be left in place until the tension chord splices are fully riveted or bolted and all other truss connections pinned and bolted. Permanent bolts in splices of butt joints of compression members and rivets or permanent bolts in railings shall not be driven or tightened until the span has been swung. Splices and field connections shall have one half of the holes filled with bolts and cylindrical erection pins (half bolts and half pins) before bolting with high-strength bolts. Splices and connections carrying traffic during erection shall have three-fourths of the holes so filled.

10.49.2 Fitting-up bolts shall be of the same nominal diameter as the high-strength bolts, and cylindrical erection pins shall be 1/32 inch larger.

10.50 PIN 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 burred at the face of the nut with a pointed tool.

10.51 MISFITS

The correction of minor misfits involving harmless amounts of reaming, cutting, and chipping will be considered a legitimate part of the erection. However, any error in the shop fabrication or deformation resulting from handling and transportation which prevents the proper assembling and fitting up of parts by the moderate use of drift pins or by a moderate amount of reaming and slight chipping or cutting, shall be reported immediately to the Inspector and his approval of the method of correction obtained. The correction shall be made in his presence. If the contract provides for complete fabrication and erection, the Contractor shall be responsible for all misfits, errors, and injuries and shall make the necessary corrections and replacements. If the contract is for erection

only, the Inspector, with the cooperation of the Contractor, shall keep a correct record of labor and materials used and the Contractor shall render within 30 days an itemized bill for the approval of the Engineer.

10.52 REMOVAL OF OLD STRUCTURE AND FALSEWORK

10.52.1 If stipulated in the agreement, the Contractor shall dismantle the old structure which, unless otherwise provided, shall be the property of the Owner, and shall store the material in the immediate vicinity of the bridge site as the Engineer may direct. If the old structure is to be re-erected, it shall be dismantled without unnecessary damage and the parts match-marked and carefully stockpiled.

10.52.2 Upon completion of the erection and before final acceptance, the Contractor shall remove all falsework, excavated or useless materials, rubbish, and temporary buildings, replace or renew any fences damaged and restore in an acceptable manner all property, both public and private, which may have been damaged during the prosecution of this work, and shall leave the bridge site and adjacent highway in a neat and presentable condition satisfactory to the Engineer. All excavated material or falsework placed in the stream channel during construction shall be removed by the Contractor before final acceptance.

10.53 METHOD OF MEASUREMENT

The weight of the metal work to be paid for under the item of structural steel shall be computed on the following basis:

10.53.1 UNIT WEIGHTS, POUNDS PER CUBIC FOOT

Aluminum, cast or wrought	173.0
Bronze, cast	536.0
Copper-alloy	536.0
Copper sheet	558.0
Iron, cast	445.0
Iron, malleable	470.0
Iron, wrought	487.0
Lead, sheet	707.0
Steel, rolled, cast, copper bearing, silicon, nickel, and stainless, all grades	490.0
Zinc	450.0

10.53.2 The weights of rolled shapes shall be computed on the basis of their nominal weights per foot as shown on the drawings, or listed in the handbooks.

10.53.3 The weights of plates shall be computed on the basis of the nominal weight for their width and thickness as shown on the drawings, plus an estimated overrun computed as one-half the "Permissible Variation in Thickness and Weight" as tabulated in Specification, "General Requirements for Delivery of Rolled Steel Plates, Shapes, Steel Piling, and Bars for Structural Use," AASHTO M 160 (ASTM A6).

10.53.4 The weight of castings shall be computed from the dimensions shown on the approved shop drawings, deducting for open holes. To this

weight shall be added 5 percent allowance for fillets and overrun. Scale weights may be substituted for computed weights in the case of castings or of small complex parts for which accurate computations of weight would be difficult.

10.53.5 The weight 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, shall not be included.

10.53.6 In computing pay weight on the basis of computed net weight the following stipulations in addition to those in the foregoing paragraphs shall apply.

(a) The weight shall be computed on the basis of the net finished dimensions of the parts as shown on the approved shop drawing, deducting for copes, cuts, clips, and all open holes, except bolt holes.

(b) The weight of heads, nuts, single washers, and threaded stick-through of all high tensile strength shop bolts, both shop and field, shall be included on the basis of the following weights:

Diameter of Bolt Inches	Weight per 100 bolts, pounds
1/2	19.7
5/8	31.7
3/4	52.4
7/8	80.4
1	116.7
1 1/8	165.1
1 1/4	212.0
1 3/8	280.0
1 1/2	340.0

(c) The weight of weld metal shall be computed on the basis of the theoretical volume from dimensions of the welds.

10.53.7 In computing pay weight on the basis of computed gross weight, the following stipulations in addition to those of paragraphs 10.53.1, through 10.53.5 above shall apply.

(a) The weight shall be figured on the basis of rectangular dimensions for all plates, and ordered over-all lengths for all structural shapes; except that (A) when parts can be economically cut in multiples from material of larger dimensions, the computed weight shall be that of the material from which the parts are cut, and (B) all material shall be ordered to produce as little waste as practicable when cut and finished by modern shop methods.

(b) No deductions from the computed weight of rolled steel shall be made for the copes, clips, sheared edges, punchings,

borings, milling or planning; or from the computed weight of castings to allow for drillings or borings.

(c) The weight of weld metal shall be computed on the basis of the theoretical volume of the dimensions of the welds. To this weight shall be added 50 percent allowance for overrun.

10.53.8 In computing pay weight on the basis of scale weights, the pay quantity of structural steel will be the shop scale weight of the fabricated members, which shall be weighed on satisfactory scales in the presence of the Inspector. If the shop paint has been applied to the completed member when weighed, 0.4 of 1 percent of the weight of the member shall be deducted from the scale weights to compensate for weight of shop paint. The weight of field bolts shall be based on the approved shipping list. No payment will be made for any weight in excess of 1 1/2 percent above the computed net weight of the whole item.

10.54 BASIS OF PAYMENT

10.54.1 The contract price for fabrication and erection of structural steel shall include all labor, materials, transportation, and shop and field painting necessary for the proper completion of the work in accordance with the contract. The contract price for fabrication without erection shall include all labor and materials necessary for the proper completion of the work in accordance with the contract.

10.54.2 Under contracts 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 posts shall be paid for as structural steel unless otherwise stipulated.

10.54.3 Payment will be made on a pound-price or a lump sum basis as required by the terms of the contract, but unless stipulated otherwise, it shall be on a pound-price basis.

10.54.4 The payment in pound-price contracts shall be based on the computed net weight of metal in the fabricated and erected structures unless it is provided that payment shall be based on computed gross weight or scale weight.

10.54.5 For members comprising both carbon steel and other special steel or material, when separate unit prices are provided for same, the weight of each class of steel in each such member shall be separately computed, and paid for at the contract unit price therefor.

10.54.6 Full-size members which are tested in accordance with the specifications, when such tests are required by the contract, shall be paid for at the same rate as for comparable members for the structure. Members which fail to meet the contract requirements, and members rejected as a result of tests, shall not be paid for by the purchaser.

SECTION 11 - BRONZE OR COPPER-ALLOY BEARING AND EXPANSION PLATES

11.1 GENERAL

Plates shall be of the kind of metal specified in the special provisions or as shown on the plans.

11.2 MATERIALS

11.2.1 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 911 shall be furnished unless otherwise specified.

11.2.2 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 No. 510 or No. 511 (previously designated as No. 1) shall be furnished unless otherwise specified.

11.2.3 METAL POWDER SINTERED BEARINGS AND EXPANSION JOINTS (Oil Impregnated)

Metal powder sintered bearings and expansion plates shall conform to the specifications for such material of the ASTM B 438, Grade 1, Type II or Grade 2, Type I.

11.3 BRONZE PLATES

Plates shall be cast according to details shown on the plans. Sliding surfaces shall be planed parallel to the movement of the spans and polished unless detailed otherwise.

11.4 COPPER-ALLOY PLATES

Plates shall be furnished according to details shown on the plans. Finishing of the rolled plates will not be required provided they have a plane, true and smooth surface.

11.5 PLACING

Bearing plates shall be accurately set in correct position as shown on the plans and shall have a uniform bearing over the whole area. Provision shall be made to keep the plates in correct position as the concrete is being placed.

11.6 MEASUREMENT AND PAYMENT

The weight to be paid for shall be the Inspector's certified shop scale weight of the plates as placed in the structure, unless otherwise provided. If specified in the contract or permitted by the Engineer, computed weights, obtained as herein described, may be made the basis of payment. Payment shall be made at the contract price per pound. Payment shall include the furnishing of material and all labor and incidental work that is required.

SECTION 12 - STEEL GRID FLOORING

12.1 GENERAL

12.1.1 Steel grid flooring shall be of the open type, or the concrete filled type as specified in the special provisions or as shown on the plans.

12.1.2 The floor shall meet the requirements for the design of steel grid floors in Division I, Article 3.27. Before fabrication or construction is undertaken the Contractor shall submit complete shop and assembly details to the Engineer for approval.

12.2 MATERIALS

12.2.1 STEEL

All steel shall conform to the Specification for Structural Steel of the AASHTO M 183 (ASTM A 36), AASHTO M 223 (ASTM A 572), Grade 50, or AASHTO M 222 (ASTM A 588). Unless the material is galvanized it shall have a copper content of 0.2 percent.

12.2.2 PROTECTIVE TREATMENT (Shop Coat)

12.2.2.1 Open type floors, preferably, shall be galvanized in accordance with the Specification for Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel Shapes, Plates, Bars, and Strip, AASHTO M 111 (ASTM A 123).

12.2.2.2 In lieu of galvanizing, the floor may be painted if specified in the special provisions. The paint shall be applied according to the specifications for Painting Metal Structures, except that dipping will be permitted. The paint shall be as specified for metal structures unless paint of other type is required by the special provisions.

12.2.3 CONCRETE

All concrete in filled steel grid floors shall conform to the specification for concrete, Section 4. The concrete and the size of aggregate shall be as specified for Class Y concrete.

12.2.4 SKID RESISTANCE

The upper edges of all members forming the wearing surface of an open type grid flooring shall be fabricated or treated to give the maximum skid resistance.

12.3 ARRANGEMENT OF SECTIONS

12.3.1 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 40 feet 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.

12.3.2 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.

12.4 PROVISION FOR CAMBER

Unless otherwise provided on the plans, provision for camber shall be made as follows:

12.4.1 Steel units so rigid that they will not readily follow the camber required shall be cambered in the shop. To provide a bearing surface parallel to the crown of the roadway, the stringers shall be canted or provided with shop-welded beveled bearing bars. If beveled bars are used they shall be placed 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.

12.4.2 Longitudinal stringers shall be mill cambered or provided with bearing strips so that the completed floor after dead load deflection shall conform to the longitudinal camber shown on the plans.

12.5 FIELD ASSEMBLY

Areas of considerable size shall be assembled before the floor is welded to its supports. The main elements shall be made continuous and sections shall be connected together along their edges by welding or bolting. The connections shall meet with the approval of the Engineer.

12.6 CONNECTION TO SUPPORTS

12.6.1 The floor shall be connected to its steel supports by welding. Before any welding is done the floor shall either be loaded to make a tight joint with full bearing or it shall be clamped down. 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.

12.6.2 The ends of all the main steel members of the slab shall be securely fastened together at the sides of the roadway for the full length of the span by means of steel plates or angles welded to the ends of the main members, or by thoroughly encasing the ends with concrete.

12.7 WELDING

All shop and field welding shall be done in accordance with Article 10.19.

12.8 REPAIRING DAMAGED GALVANIZED COATINGS

All galvanizing that has been chipped off or damaged in handling or transporting, or in welding or riveting, shall be repaired by field galvanizing by the application of a paste composed of approved zinc powder and flux with a minimum amount of water. The places to be coated shall be thoroughly cleaned, including removal of slag on welds, before the paste is applied. The surface to be coated shall first be heated with a torch to a sufficient temperature so that all metallics in the paste are melted when applied to the heated surface. Extreme care shall be taken to see that the galvanized surfaces are not damaged by the torch. The flux in the paste will cause a black substance to appear on the surface of the coated parts, and this black substance shall be removed by wiping off with waste or by the quick application of cold water.

12.9 CONCRETE FILLER

12.9.1 Floor types 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.

12.9.2 If metal form strips are used they shall fit tightly on the bottom flanges of the floor members and be placed in short lengths so as to extend only about 1 inch 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.

12.9.3 The concrete shall be mixed, placed, and cured in accordance with the requirements of Section 4. 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.

12.10 PAINTING

12.10.1 Flooring furnished without galvanizing, but with a shop coat of paint shall be given two field coats of paint in accordance with the requirements of Section 14.

12.10.2 If a structural steel plate is used on the bottom of a filled type floor, the bottom surface of the plate shall be painted one shop coat and two field coats of paint.

12.11 MEASUREMENT AND PAYMENT

Payment for steel grid floor, open or concrete filled type, shall include the furnishing of all materials, equipment, tools, and labor necessary for the satisfactory completion of the work. Payment will be made on the basis of the number of square feet of steel grid floor complete in place, unless otherwise specified.

SECTION 13 - RAILINGS

13.1 GENERAL

Railings for bridges shall include all work constructed above the top of sidewalk, top of curb more than six inches wide or, if a sidewalk or curb is not used, above the top of the roadway. Railings for wingwalls or retaining walls shall include all work above the top of wall, or if used, top of curb or top of sidewalk. The item shall include the furnishing of all material, equipment, tools, supplies, and labor necessary for the proper construction of the railing as shown on the plans or as provided in the special provisions. Payment will be as shown on the plans or as provided in the special provisions.

13.2 MATERIALS

All materials shall conform to the requirements of the applicable AASHTO Material Specifications, the plans, or the special provisions.

13.3 LINE AND GRADE

The line and grade of the railing shall be true to that shown on the plans, and shall not follow any unevenness in the superstructure. Unless otherwise specified or shown on the plans, the handrail and curbs on bridges, whether superelevated or not, shall be vertical.

METAL RAILING

13.4 CONSTRUCTION

13.4.1 Fabrication and erection shall be done in accordance with the requirements of Section 10. In the case of welded railings, all exposed joints shall be finished by grinding or filing after welding to give a neat appearing job.

13.4.2 Metal railings shall be carefully adjusted prior to fixing in place to insure proper matching at abutting joints, correct alignment, and camber throughout their length. Holes for field connections shall be drilled with the railing in place in the structure at proper grade and alignment. Welding may be substituted for rivets in field connections with the approval of the Engineer.

13.5 PAINTING

Unless otherwise specified, metal railing shall be given one shop coat of paint, and three coats of paint after erection. Painting shall conform to the requirements of Section 14.

CONCRETE RAILING

13.6 GENERAL

In no case shall concrete railings be placed until the centering or falsework for the span has been released, rendering the span self-supporting.

13.7 MATERIALS

Except as modified herein, materials shall conform to the requirements of Sections 4 and 5.

13.8 RAILINGS CAST-IN-PLACE

13.8.1 The portion of the railing or parapet which is to be cast-in-place shall be constructed in accordance with the requirements of Section 4. Special care shall be exercised to secure smooth and tight-fitting forms which can be rigidly held in line and grade and removed without injury to the concrete.

13.8.2 Forms shall either be of single width boards or shall be lined with suitable material which shall meet with the approval of the Engineer. Form joints in plane surfaces will not be permitted.

13.8.3 All moldings, panel work, and bevel strips shall be constructed according to the detail plans with neatly mitered joints and all corners in the finished work shall be true, sharp, and clean-cut and shall be free from cracks, spalls, or other defects.

13.9 PRECAST RAILS

13.9.1 Moist tamped mortar precast members shall be made of a mixture of cement and sand approximately in the proportions of one part of cement to two and one-half parts of sand. The sand shall be specially selected for color and grading. The sand shall be screened through a screen having 1/8 inch square meshes, and all oversize particles shall be discarded. Only sufficient water shall be used in mixing to permit the immediate removal of the member from the mold.

13.9.2 Moist tamped mortar precast members shall be cast in mortar-tight metal or metal lined molds. The precast members shall be removed from the molds as soon as practicable and shall be kept damp for a period of at least 10 days. During this period they shall be protected from the sun and from wind. Any members that show checking or soft corners or surfaces shall be rejected. The method of storage and handling shall be such as to preserve true and even edges and corners, and any precast members which become chipped, marred, or cracked before or during the process of placing shall be rejected.

13.9.3 In the construction of cast-in-place railing caps and copings built in connection with precast balusters, the balusters shall be protected from staining and disfigurement during the process of placing and finishing the concrete.

13.10 SURFACE FINISH

The surfaces of railings shall conform to the requirements of Section 4.

13.11 EXPANSION JOINTS

Expansion joints shall be so constructed as to permit freedom of movement. After all other work is completed, all loose or thin shells of mortar likely to spall under movement shall be carefully removed from all expansion joints by means of a sharp chisel.

STONE AND BRICK RAILING

13.12 GENERAL

Unless otherwise specified, the work on masonry or brick railings and parapets shall be done in accordance with the requirements of these specifications for the particular class of work involved. The work shall be done in accordance with the detailed plans, the workmanship shall be first class in every particular, and the finished construction shall be neat in appearance and true to line and grade.

WOOD RAILING

13.13 GENERAL

Wood railings shall be constructed according to the requirements of Sections 20 and 21.

13.14 MEASUREMENT AND PAYMENT

13.14.1 Payment for railing shall include all materials, tools, equipment, supplies, labor, and other costs necessary for the satisfactory completion of the work.

13.14.2 The reinforcement steel included in payment for rail shall be determined as follows: The portion of slab or beam bars which projects into the handrail shall be paid for as metal reinforcement, but the portion of the handrail steel which extends into the slab or beams shall be considered as part of the handrail.

13.14.3 Payment will be made on the basis of the number of linear feet of railing measured along the centerline of the railing. When steel railings are shown on steel structures and no separate bid is taken for railing, the railing will be paid for at the price bid per pound for structural steel.

SECTION 14 - PAINTING METAL STRUCTURES

14.1 GENERAL

14.1.1 DESCRIPTION

The painting of metal structures shall include the preparation of the metal surfaces, the application, protection, and drying of the paint coatings, the protection of pedestrian, vehicular, or other traffic upon or underneath the structure, the supply of all tools, equipment, scaffolding, labor, and materials necessary for completion of the work involved in painting the exposed surfaces of metal structures.

14.1.2 WEATHER CONDITIONS

14.1.2.1 Paint shall be applied only on thoroughly dry surfaces and during period of favorable weather. Painting will not be permitted when the atmospheric temperature is at or below 40° F when using vinyl, alkyd, and organic materials, and 50° F. when using inorganic zinc, or when the humidity exceeds 85 percent at the site of the work, or when freshly painted surfaces may become damaged by rain, fog, or dust, or when it can be anticipated that the atmospheric temperature will drop below 40°F. during the drying period, except as provided herein for painting in enclosures.

14.1.2.2 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. 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 no additional compensation will be allowed therefor.

14.1.2.3 All blast cleaning, except that performed within closed buildings, and all painting shall be performed during daylight hours unless the terms of the contract prohibit work being performed during daylight hours.

14.2 PAINT SYSTEM AND COLOR

The paint system to be applied shall consist of one set forth in the following table and as modified in the special provisions.

	High Pollution and Coastal	Mild Climate	Mild Climate or Spot Painting
Pre-treatment or Undercoat	Vinyl Wash	Inorganic Zinc 2 applications- 4 mils. total	Organic Zinc 2 applications- 3 mils. total
Undercoat or Pre-treatment	Vinyl Primer- Red Iron Oxide Applications 1 and 3	Vinyl Wash	Vinyl Wash
Undercoat or Pre-treatment	Vinyl Primer- Titanium Dioxide Applications 2 and 4 Total 4 mils. undercoat		
Finish	Vinyl 2 applications- 2 mils. total	Alkyd 1 applications- 1 1/2 mils. total	Vinyl 2 applications 2 mils. total
Total System	6 mils.	5 1/2 mils.	5 mils.

Notes:

1. Paint system shown for severe areas are satisfactory in less severe areas.

2. Paints shown are available in most desired colors.

3. Coastal - within 1,000 feet ocean or tidal water. High Pollution--air pollution environment such as industrial areas. Mild--other than coastal area not in air pollution environment.

4. Paints shall conform to the material requirements as set forth in AASHTO Materials Specification. (Pending adoption by Materials Committee.)

5. Finish coat of vinyl and alkyd for mild climate and spot systems may be interchanged.

6. Other paints and paint systems may be specified at the discretion of the owner.

14.3 CLEANING OF SURFACES

14.3.1 All exposed surfaces of structural steel, except galvanized or metalized surfaces, shall be cleaned and painted.

14.3.2 All surfaces of new structural steel or surfaces which are to be painted with inorganic zinc shall be blast cleaned unless otherwise specified in the special provisions, or approved in writing by the Engineer.

14.3.3 In repainting existing steel structures where partial cleaning is required, the method of cleaning will be specified in the special provisions. Any damage to sound paint, on areas not designated for treatment, resulting from the Contractor's operations shall be repaired by him at his expense to the satisfaction of the Engineer.

14.3.4 Cleaning of metal surfaces shall be performed as specified herein or as set forth in the special provisions. Cleaning methods shall conform to the following:

14.3.4.1 BLAST CLEANING

14.3.4.1.1 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 be a grading suitable to produce satisfactory results. The use of other abrasives will not be permitted unless approved in writing by the Engineer.

14.3.4.1.2 Unwashed beach sand containing salt or excessive amounts of silt will not be allowed.

14.3.4.1.3 All dirt, mill scale, rust, old paint, and other foreign material shall be removed from steel surfaces by an approved blast cleaning apparatus. Blast cleaning shall be sufficient to give the surface the appearance as specified in SSPC 10 - Near White, and shall leave all surfaces with a dense and uniform anchor pattern of not less than one mil. as measured with an approved surface profile comparator.

14.3.4.1.4 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.

14.3.4.1.5 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 recleaned by the Contractor at his expense.

14.3.4.2 STEAM CLEANING

14.3.4.2.1 All dirt, grease, loose chalky paint, or other foreign material which 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 to sound paint or metal surface by the Contractor at his expense.

14.3.4.2.2 A detergent shall be added to the feed water of the steam generator. The detergent shall be of such composition and shall be added in such quantity that the cleaning as provided in the above paragraph is accomplished.

14.3.4.2.3 Any residue, detergent, or other foreign material which may accumulate on cleaned surfaces shall be removed by flushing with fresh water.

14.3.4.2.4 Steam cleaning shall not be performed more than two weeks prior to painting or other phases of cleaning.

14.3.4.2.5 Subsequent painting shall not be performed until the cleaned surfaces are thoroughly dry and in no case in less than 24 hours after cleaning.

14.3.4.3 HAND CLEANING

14.3.4.3.1 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.

14.3.4.3.2 Pneumatic chipping hammers shall not be used unless authorized in writing by the Engineer.

14.4 APPLICATION

14.4.1 The Contractor shall notify the Engineer, in writing, at least one week in advance of the date cleaning and painting operations are to begin.

14.4.2 Painting shall be done in a neat and workmanlike manner. Unless otherwise specified, paint shall be applied by brush, spray, or roller, or any combination thereof peculiar to the paint being applied.

14.4.3 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 which 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.

14.4.4 Brushes, when used, shall have sufficient body and length of bristle to spread the paint in a uniform film. Paint shall be evenly spread and thoroughly brushed out.

14.4.5 On all surfaces which 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.

14.4.6 Rollers, when used, shall be of a type which do not leave a stippled texture in the paint film.

14.4.7 A water trap acceptable to the Engineer shall be furnished and installed on all equipment used in spray painting.

14.4.8 Mechanical mixers shall be used to mix paint. Prior to applying, the 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.

14.4.9 Paints specified are formulated ready for application and no thinning will be allowed unless otherwise provided in the applicable materials specification for the paint being used.

14.4.10 The dry film thickness of the paint will be measured in place with a calibrated magnetic film thickness gage.

14.4.11 The thickness of each application shall be limited to that which will result in uniform drying throughout the paint film.

14.4.12 Succeeding applications of paint shall be of such shade as to contrast with the paint being covered.

14.4.13 Zinc-rich primers shall be applied by spray methods. On areas inaccessible to spray application, the paint may be applied by brush or daubers.

14.4.14 Mechanical mixers shall be used in mixing the primer. After mixing, the zinc-rich primers shall be strained through a metal 30-60 mesh screen or a double layer of cheesecloth immediately prior to or during pouring into the spray pot.

14.4.15 An agitating spray pot shall be used in all spray application of zinc-rich primers. The agitator or stirring rod shall reach to within 2 inches 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.

14.4.16 Cured organic zinc-rich primer shall be free from dust, dirt, salt, or other deleterious deposits and thoroughly dry before applying vinyl wash primer.

14.4.17 Vinyl wash primer shall not be applied more than 72 hours before application of finishing coat paint. The vinyl wash primer shall be applied by spraying to produce a uniform wet film on the surface.

14.4.18 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 undercoats to the specified thickness.

14.4.19 Surfaces exposed to the atmosphere and which would be inaccessible for painting after erection shall be painted the full number of applications prior to erection.

14.4.20 In addition, the application of inorganic zinc paints shall conform to the following:

14.4.20.1 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 the inorganic zinc paint. The hose from pot to nozzle shall not be more than 75 feet long, nor be used more than 15 feet above or below the pot.

14.4.20.2 Succeeding coats shall be applied within the following 24 hours. A minimum of 30 minutes shall elapse between applications.

14.4.20.3 In areas where "mud-cracking" occurs in the inorganic zinc paint, it shall be scraped back to soundly bonded paint, and recoated to the same thickness by the same methods specified for the original coat.

14.4.20.4 Paint shall be cured for 48 hours at a relative humidity of at least 45 percent 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 3 weeks after the inorganic zinc paint is applied, or when there is evidence of dust, dirt, salt, or other deleterious deposits on the inorganic zinc paint.

14.4.20.5 Vinyl wash primer shall not be applied more than 48 hours before the application of finish coats.

14.5 PROTECTION AGAINST DAMAGE

14.5.1 The Contractor shall provide protective devices as necessary to prevent damage to the work and to other property or persons from all cleaning and painting operations.

14.5.2 Paint or paint stains which result in an unsightly appearance on surfaces not designated to be painted shall be removed or obliterated by the Contractor at his expense.

14.5.3 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.

14.5.4 All painted surfaces that are marred or damaged as a result of operations of the Contractor shall be repaired by the Contractor, at his expense, with materials and to a condition equal to that of the coating specified herein.

14.5.5 Upon completion of all painting operations and of any other work that would cause dust, grease, or other foreign materials to be deposited upon 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.

14.6 PAINTING GALVANIZED SURFACES

14.6.1 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.

14.6.2 After washing, all areas shall be roughened by abrasive blasting using an abrasive that is no larger than 30 mesh. Galvanizing shall not be removed by this operation.

14.6.3 After preparation, all galvanized surfaces that are to be painted shall be covered with one application of zinc dust-zinc oxide primer. Federal Specification TT-P-641, Type II. The zinc dust-zinc oxide paint shall be applied by spraying to produce a complete covering of the galvanized surfaces.

14.6.4 After the application of zinc dust-zinc oxide paint, one application of pre-treatment, 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.

14.6.5 Such surfaces shall then be covered with two separate applications of white tint base vinyl finish coat, sufficient to completely cover the preceding color. Paint for the first application shall be tinted with a compatible coloring agent to slightly contrast with the color of the second application. The final finish application shall be tinted to match the color shown on the plans or specified in the special provisions.

SECTION 15 - PROTECTION OF EMBANKMENTS AND SLOPES

15.1 GENERAL

15.1.1 This work consists of furnishing and placing a protective covering of erosion resistant material for riprap as slope or pier foundation protection. The work shall be done in reasonably close conformity to the plans and specifications.

15.1.2 The areas to receive riprap or slope protection of any kind shall be dressed smooth to the slopes or shapes called for on the plans and shall be free from stumps, organic matter, or waste material. Generally, a toe trench should be provided in which to key the bottom course of riprap. A filter blanket should be provided where it is anticipated that there may be migration of fines through the riprap. These items should be shown on the plans or called for in the project specifications.

15.1.3 All material, regardless of type or kind, shall be placed reasonably close to the lines called for on the plans.

15.2 MATERIALS

15.2.1 All stone, regardless of use, shall be clean (free from organic matter) durable, angular with fractured faces, nearly rectangular in shape with a breadth or thickness at least one-third its length and have a gradation dependent upon maximum size as determined by the Engineer.

15.2.2 Project plans or specifications will state the size and quality requirements of stone to be used for the various classes of work. Sizes shown in the following table are recognized by these specifications.

MINIMUM PERCENTAGE LARGER THAN

Classes

Rock Size	8 Ton	4 Ton	2 Ton	1 Ton	1/2 Ton	1/4 Ton	Light	Facing	Filter No. 1	Filter No. 2
8 Ton	50	0								
4 Ton	95	50	0							
2 Ton	--	95	50	0						
1 Ton	--	--	95	50	0					
1/2 Ton	--	--	--	95	50	0				
1/4 Ton	--	--	--	--	95	50	0			
200 Pounds	--	--	--	--	--	--	50	0		
75 Pounds	--	--	--	--	--	90	--	50		
5 Pounds	--	--	--	--	--	--	90	90	0	
No. 4	--	--	--	--	--	--	--	--	50	0
No. 200	--	--	--	--	--	--	--	--	95	90

The table above sets out minimum requirements for the large stone per class. It is understood that the Contractor will furnish material well graded with smaller stones to the extent that a homogeneous blanket of riprap will result with all interstices reasonably well filled with rock. Quality requirements for rock to be furnished under these specifications shall be checked prior to use by the stipulated tests and at appropriate times throughout the life of the project as determined by the Engineer.

15.3 LOOSE RIPRAP FOR SLOPES

15.3.1 Stone for riprap shall be placed on the prepared or natural slope in a manner which will produce a reasonably well graded mass of stone with the minimum practicable percentage of voids, and shall be constructed to the lines, grades, and thicknesses shown on the drawing, or as directed. Riprap protection shall be placed to its full course thickness at one operation and in such a manner as to avoid displacing the underlying material. Placing of riprap protection in layers or by dumping into chutes or by similar methods likely to cause segregation will not be permitted. The larger stones shall be well distributed and the entire mass of stones shall be roughly graded to conform to approximate gradation specified in Article 15.2. All material going into riprap protection shall be so placed and distributed that there will be no large accumulations or areas composed largely of either the larger or smaller sizes of stone, and the entire mass of stones shall be roughly graded to conform to the approximate gradation specified in Article 15.2. It is the intent of the specifications to produce a fairly compact riprap protection in which all sizes of material are placed in their proper proportions. Hand placing or rearranging of individual stone by mechanical equipment may be required to the extent

necessary to secure the results specified above. The desired distribution of the various sizes of stone throughout the mass may be obtained, at the option of the Contractor, either by selective loading at the quarry, or controlled dumping of successive loads during placing or by a combination of these methods. Unless otherwise authorized by the Engineer, the riprap protection shall be placed in conjunction with the construction of the enbankment with only sufficient lag in construction of the riprap protection as may be necessary to prevent mixture of embankment and riprap material.

15.3.2 A tolerance of plus or minus 8 inches from the thicknesses shown on the drawing will be allowed in the finished surface of the riprap protection, except that either extreme of such tolerance shall not be continuous over an area greater than 200 square feet. The tolerance limit will be determined on the basis of the average surface elevation within two square feet.

15.4 MORTAR RIPRAP FOR SLOPES

15.4.1 Stone for this purpose shall, as far as practicable, be selected as to size and shape in order to secure fairly large, flat-surfaced stone which will lay up with a true and even surface and a minimum of voids. These stones shall be placed first and roughly arranged in close contact, the largest stones being placed near the base of the slope. The spaces between the larger stones shall be filled with stones of suitable size, leaving the surface smooth, reasonably tight, and conforming to the contour required. In general, the stone shall be laid with a degree of care that will insure for plane surfaces a maximum variation from a true plane of not more than 1-1/2 inches in 4 feet. Warped and curved surfaces shall have the same general degree of accuracy as specified above for plane surfaces.

15.4.2 As each of the larger stones is placed, it shall be surrounded by fresh mortar and adjacent stones shall be shoved into contact. After the larger stones are in place all of the spaces or openings between them shall be filled with mortar and the smaller stones then placed by shoving them into position, forcing excess mortar to the surface and insuring that each stone is carefully and firmly bedded laterally.

15.4.3 After the work has been completed as above described, all excess mortar forced up shall be spread uniformly to completely fill all surface voids. All surface joints shall then be roughly pointed up either with flush joints or with shallow, smooth raked joints.

15.4.4 Weep holes shall be provided through the riprap cover as shown on the plans or as directed by the Engineer.

15.4.5 Mortar shall consist of one part cement complying with Article 4.2.1.1. and three parts sand complying with Article 4.2.3, thoroughly mixed with water to have a thick creamy consistency. Mortar shall not be placed in freezing weather. During hot, dry weather the work shall

be protected from the sun and kept moist for a minimum of three days after placement.

15.4.6 Rock shall be kept wet during placing of the mortar.

15.5 STONE RIPRAP FOR FOUNDATION PROTECTION

15.5.1 Stone shall be placed as nearly as is practical to the locations and areas called for on the plans.

15.5.2 When placed under water, free dumping will 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.

15.6 CONCRETE RIPRAP IN BAGS

15.6.1 In general this type material shall be used only where it can be placed in the dry.

15.6.2 Concrete for riprap in bags shall be Class "C" concrete complying with Article 4.5.

15.6.3 Heavy burlap bags 10 oz. about 19-1/2" x 36" with inside seams are preferred. If sacks of larger sizes are used the ends shall be folded to secure close contact with adjacent bags and to contain approximately 2/3 cu. ft. of concrete.

15.6.4 The bags shall be securely tied or folded over and immediately placed in the work. If bags are folded the fold shall be placed underneath the bag for headers and against the previously placed bag for stretchers. Each course shall be thoroughly tamped into place so that close contact with underlying and adjacent bags is obtained. No more than four horizontal courses shall be laid above concrete not yet having its initial set. At the start of each day's work, previously placed sacks shall be moistened and dusted heavily with cement.

15.6.5 Weep holes shall be provided through the riprap cover as shown on the plans or as directed by the Engineer.

15.7 CONCRETE SLAB RIPRAP

15.7.1 GENERAL

Concrete slab riprap may be either cast-in-place slabs or precast slabs manufactured on the job or at a regular masonry unit manufacturing plant. If reinforcement is required, it shall be furnished and placed as shown on the plans. All blocks shall be of the limiting dimensions shown on the plans.

15.7.2 MANUFACTURE

Cast-in-place slabs or precast slabs manufactured on the job shall be made of Class "A" concrete complying with the requirements of Section 4

except that the minimum compressive strength of the concrete shall be 1,800 pounds per square inch. All edges shall be tooled and the exposed surfaces shall be a wood float and fiber brush finish.

15.7.2.1 Plant manufactured slabs shall be uniform in texture with true sharp edges. Tooling of edges and brush finish will not be required. Plant manufactured blocks shall comply with ASTM Specification C 145, for Grade N, Type II.

15.7.2.2 Either conventional aggregate complying with Articles 4.2.3 and 4.2.4 or light weight aggregate complying with AASHTO M 195 may be used in manufacture of the blocks.

15.7.3 PLACING

A trench of the dimensions shown on the plans or as given by the Engineer shall be dug at the toe of the slope and the slope shall be dressed to the lines and grades given by the Engineer. Excess material removed in dressing slopes shall be used in filling low areas and any excess not required for this purpose shall be spread on adjacent highway slopes as directed by the Engineer. Filled areas shall be compacted. If it is necessary to import material for filling depressions and low spots to bring slopes to lines and grades, importation of such material only will be paid for as extra work. Placing imported material will be considered a part of the work of dressing the slopes. The riprap shall be placed in blocks of the dimensions shown on the plans. Unless otherwise specified, blocks shall be laid in horizontal courses and successive courses shall break joints with preceding courses. Joint details shall be as shown on the plans, but if not shown, horizontal joints and joints up the slope in either type construction shall be 3/4", filled with 1 to 3 grout and raked 3/4".

15.7.3.1 Weep holes shall be provided through the riprap cover as shown on the plans or as directed by the Engineer.

15.7.3.2 The Contractor shall maintain the riprap protection as may be necessary to prevent mixture of embankment and riprap material. The Contractor shall maintain the riprap protection until accepted and any material displaced by any cause, shall be replaced at no additional cost to the owner, to the lines and grades shown on the drawing.

15.8 FILTER OR BEDDING MATERIAL

15.8.1 Pit or quarry run material of the size specified and complying with Article 15.2 will be acceptable.

15.8.2 Stone shall be placed as nearly as is practical to the locations and areas called for on the plans.

15.8.3 When placed under water, free dumping will 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.

15.9 MEASUREMENT

15.9.1 LOOSE RIPRAP FOR SLOPES

Loose riprap for slopes may be measured for payment on either a square yard, cubic yard, or weight basis as specified. If measured on a square yard basis, the quantity measured will be that actually placed to the limiting dimensions shown on the plans or the plan dimensions as may be revised by the Engineer.

15.9.2 MORTAR RIPRAP FOR SLOPES

Mortar riprap for slopes will be measured for payment on a square yard basis. The quantity measured will be that actually placed to the limiting dimensions shown on the plans or the plan dimensions as may be revised by the Engineer.

15.9.3 STONE RIPRAP FOR FOUNDATION PROTECTION

Unless otherwise specified, stone riprap will be measured for payment on a ton basis. Weighing shall be done in the presence of an Inspector in the hauling vehicles either at the quarry or at or near the point of placement as may be directed by the Engineer. The quantity measured for payment will be that actually placed in accordance with instructions given by the Engineer.

15.9.4 CONCRETE RIPRAP IN BAGS

Unless otherwise specified concrete riprap in bags will be measured for payment on a cubic yard basis. The quantity measured will be that actually placed to the limiting dimensions shown on the plans or the plan dimensions as may be revised by the Engineer.

15.9.5 CONCRETE SLAB RIPRAP

15.9.5.1 "Preparation of Slopes" will be measured for payment on a square yard unit. The quantity measured will be that actually prepared for coverage by riprap as required by plan dimensions or plan dimensions as may be revised by the Engineer. Excavated area for toe trenches or curbs, if required, will be included in these limiting dimensions.

15.9.5.2 "Concrete Slab Riprap" will be measured for payment on a square yard unit. The quantity measured will be that actually placed within the limiting dimensions called for on the plans or plan dimensions as may be revised by the Engineer. Curbing, if required, will be included in these limiting dimensions.

15.9.6 FILTER OR BEDDING MATERIAL

Filter or bedding material will be measured for payment on a cubic yard, square yard, or weight basis as called for in the project specifications. The quantity measured will be that actually placed to the limiting dimensions shown on the plans or the plan dimensions as may be revised by the Engineer. Measurements on a square yard basis shall be measured parallel to the finished surface.

15.10 PAYMENT

15.10.1 LOOSE RIPRAP FOR SLOPES

Loose riprap for slopes measured in accordance with Article 15.9.1 will be paid for at the price bid per square yard, per cubic yard, or per ton as set forth in the project specifications.

15.10.2 MORTAR RIPRAP FOR SLOPES

Mortar riprap for slopes measured in accordance with Article 15.9.2 will be paid for at the price bid per square yard.

15.10.3 STONE RIPRAP FOR FOUNDATION PROTECTION

Stone riprap for foundation protection measured in accordance with Article 15.9.3 will be paid for at the price bid per ton unless otherwise specified.

15.10.4 CONCRETE RIPRAP IN BAGS

Concrete riprap in bags measured in accordance with Article 15.9.4 will be paid for at the price bid per cubic yard unless otherwise specified.

15.10.5 CONCRETE SLAB RIPRAP

15.10.5.1 Payment for preparation of slopes will be made at the unit price bid per square yard therefor, which price and payment shall be full compensation for furnishing and placing all materials including labor, tools, equipment, and incidentals necessary to complete preparation of the area to be covered, including excavation and backfill of toe trenches and curbs if required. Borrow material, if required, will be paid for as extra work as set forth in Article 15.7.3

15.10.5.2 Payment for concrete slab riprap will be at the unit price bid per square yard therefor, which price and payment shall be full compensation for furnishing all materials, including labor, equipment, tools, and incidentals necessary to complete the work.

15.10.6 FILTER OR BEDDING MATERIAL

Filter or bedding material measured in accordance with Article 15.9.6 will be paid for on the cubic yard, square yard, or weight basis as called for in the project specifications.

15.10.7 GENERAL

Payment for riprap of the various classes at the unit prices bid will include full and complete compensation for all labor, materials, equipment, or other incidental expense in connection with preparation of subgrade, excavating and backfilling toe trenches where required, furnishing and placing the stone, slabs, grout, mortar, reinforcing steel, if required, and all other work and incidental material required to complete the work in accordance with the plans and specifications.

SECTION 16 - CONCRETE CRIBBING

16.1 GENERAL

16.1.1 The construction of concrete cribbing shall consist of the furnishing and installation of reinforced concrete crib members and the placing of the interior filling materials. The crib members shall be cast in the proportions and in conformance with the general requirements set forth for precast concrete bearing piles. Dowels, where used, shall be of galvanized steel not less than 1 inch in diameter and of the required length.

16.1.2 Casings for dowels shall be of galvanized steel pipe not less than 1-1/4 inches in diameter.

16.1.3 The details of the crib members and their arrangement shall be as shown on the plans. If specific details for reinforcement are not shown on the plans, or if the Contractor is permitted to purchase the crib members from manufacturers, he shall submit detailed specifications and plans for the approval of the Engineer, and such plans must be approved before delivery of the material is begun.

16.1.4 All members shall be free from depressions and spalled, patched, or plastered surfaces or edges, or any other defects which may impair their strength or durability. Cracked or otherwise defective members will be rejected.

16.2 CONSTRUCTION

16.2.1 The foundation or bed for the cribbing shall be firm and shall be approved by the Engineer before any of the crib work is placed. In general, transverse concrete sill members shall be used to support the lower cribbing course. Crib members shall be carefully handled and erected in such manner as to avoid any injury due to shock or impact. Each member shall be secured by approved interlocking details or by means of dowels passing through galvanized casings. Any members which become cracked or otherwise injured during erection shall be completely renewed and replaced.

16.2.2 The filling for the interior of the crib shall progress simultaneously with the erection of the cribbing, and shall be of approved material placed in layers not to exceed 12 inches in thickness and tamped or consolidated to the satisfaction of the Engineer.

16.3 MEASUREMENT AND PAYMENT

Concrete cribbing will be paid for at the contract price per cubic foot for concrete cribbing complete in place. This price shall include all materials, equipment, tools, and labor incidental to the satisfactory erection of the cribbing, including necessary excavation. The volume to be paid for will be the actual net volume of the concrete in the crib members as shown on the plans. The filling for the interior of the crib will be paid for at the contract price per cubic yard for crib filling in place.

SECTION 17 - WATERPROOFING

17.1 GENERAL

When specified on the plans or in the special provisions, surfaces shall be waterproofed as specified herein.

17.2 MATERIALS

17.2.1 MORTAR

Mortar for the protective course shall conform to the provisions of Article 6.2.2.

17.2.2 ASPHALT

17.2.2.1 Waterproofing asphalt shall conform to the Specification for Asphalt for Dampproofing and Waterproofing, AASHTO M 115 (ASTM D 449). NOTE: Type I is for use below ground and Type II for use above ground.

17.2.2.2 Primer for use with asphalt in waterproofing shall conform to the Specification for Primer for Use With Asphalt in Dampproofing and Waterproofing, AASHTO M 116 (ASTM D 41).

17.2.3 BITUMEN

17.2.3.1 Waterproofing bitumen shall conform to the Specification for Coal-Tar Bitumen for Roofing, Dampproofing, and Waterproofing, AASHTO M 118 (ASTM D450). Type II shall be furnished unless otherwise specified.

17.2.3.2 Primer for use with coal-tar bitumen in dampproofing and waterproofing shall conform to the Specification for Creosote for Priming Coat with Coal-Tar Pitch in Dampproofing and Waterproofing, AASHTO M 121 (ASTM D 43).

17.2.4 FABRIC

The fabric shall conform to the Specification for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing, AASHTO M 117 (ASTM D 173).

17.2.5 TAR FOR ABSORPTIVE TREATMENT

Tar for absorptive treatment shall be a liquid water-gas tar which conforms to the following requirements:

Specific gravity 77/77° F	1.030 to 1.100
Specific viscosity at 104° F (Engler), not more than	3.0
Total distillate, percent by weight, to 572° F, not more than	50.0
Bitumen (soluble in carbon disulphide), not less than, percent	98.0
Water, not more than, percent	3.0

17.2.6 TAR SEAL COAT

Tar seal coat shall conform to the Specification for Tar for Use in Road Construction, AASHTO M 52, Grade RTCB-5 (ASTM D 490).

17.2.7 JOINT FILLERS

17.2.7.1 Filler for use in horizontal joints in waterproofing work shall be a straight refined oil asphalt conforming to the following requirements:

Flash point: Not less than 450° F.
Softening point: 120° F to 130° F.
Penetration: At 32° F, 200 grams, 1 minutes, not less than 15. At 77° F, 100 grams, 5 seconds, 50 to 60. At 115° F, 50 grams, 5 seconds, not more than 300.
Loss on heating: At 325° F, 50 grams, 5 hours, not more than 0.5 percent.
Ductility: At 77° F, 5 centimeters per minute, not less than 85.
Total bitumen (soluble in carbon disulphide): Not less than 99.5 percent.

17.2.7.2 Filler for use in vertical joints in waterproofing work shall be an asphalt conforming to the requirements specified above for horizontal joint filler, to which has been added 20 percent, by weight, of asbestos fiber. The incorporation of the asbestos fiber with the asphalt shall be done at the factory of the manufacturer to insure a uniform distribution of the fiber throughout the mix.

17.2.8 INSPECTION AND DELIVERY

17.2.8.1 All waterproofing 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 which 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.

17.2.8.2 Factory inspection is preferred, but, in lieu thereof, the Engineer may order that representative samples, properly identified, be sent to him for test prior to shipment of the materials. After delivery of the materials, representative check samples shall be taken which shall determine the acceptability of the materials.

17.2.8.3 All materials shall be delivered on the work in original containers, plainly marked with the manufacturer's brand or label.

17.3 STORAGE OF FABRIC

The fabric shall be stored in a dry, protected place. The rolls shall not be stored on end.

17.4 PREPARATION OF SURFACE

17.4.1 All concrete surfaces which are to be waterproofed shall be reasonably smooth, and free from projections or holes which might cause puncture of the membrane. The surface shall be dry, so as to prevent the formation of steam when the hot asphalt or tar is applied, and, immediately before the application of the waterproofing, the surface shall be thoroughly cleaned of dust and loose materials.

17.4.2 No waterproofing shall be done in wet weather, nor when the temperature is below 35° F, without special authorization from the Engineer. Should the surface of the concrete become temporarily damp, it shall be covered with a 2-inch 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.

17.5 APPLICATION - GENERAL

17.5.1 Asphalt shall be heated to a temperature between 300° and 350° F, and tar for hot application shall be heated to a temperature between 200° and 250° F with frequent stirring to avoid local overheating. The heating kettles shall be equipped with thermometers.

17.5.2 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.

17.5.3 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 2 inches wide. All end laps shall be at least 12 inches.

17.5.4 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:

17.5.4.1 Beginning at the low point of the surface to be waterproofed, a section about 20 inches wide and the full length of the surface shall be mopped with the hot asphalt or tar, and there shall be rolled into it, immediately following the mopping, the first strip of fabric, or 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 than be mopped with hot asphalt or tar, 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 or tar and the third strip of fabric "shingled" on so as to lap the first strip not less than 2 inches. This process shall be continued until the entire surface is covered, each strip of fabric lapping at least 2 inches over the last strip. The entire surface shall then be given a final mopping of hot asphalt or tar.

17.5.4.2 The completed waterproofing shall be a firmly bonded membrane composed of two layers of fabric and three moppings of asphalt or tar, 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 or tar.

17.5.4.3 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 12 gallons of asphalt or tar shall be used for each 100 square feet of finished work, and on vertical surfaces not less than 15 gallons 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 or tar. Special care shall be taken at all laps to see that they are thoroughly sealed down.

17.6 APPLICATION - DETAILS

17.6.1 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.

17.6.2 All flashing at curbs and against girders, spandrel walls, etc., shall be done with separate sheets lapping the main membrane not less than 12 inches. 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.

17.6.3 Joints which are essentially open joints but which are not designed to provide for expansion shall first be caulked with oakum and lead wool and then filled with hot joint filler.

17.6.4 Expansion joints, both horizontal and vertical, shall be provided with sheet copper or lead in "U" or "V" form in accordance with the details. 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.

17.6.5 At the ends of the structure the membrane shall be carried well down on the abutments and suitable provision made for all movement.

17.7 DAMAGE PATCHING

Care shall be taken to prevent injury to the finished membrane by the passage over it of men or wheelbarrows, or by throwing any material on it. Any damage which may occur shall be repaired by patching. Patches shall extend at least 12 inches beyond the outermost damaged portion and the second ply shall extend at least 3 inches beyond the first.

17.8 PROTECTION COURSE

17.8.1 Over the waterproofing membrane, constructed as specified above, there shall be constructed a protection course which, unless otherwise specified or shown on the plans shall be a 2-inch course of mortar mixed in the proportion of one part Portland cement and two parts sand. This mortar course shall be reinforced midway between its top and bottom surfaces with wire netting of 6 inch mesh and No. 12 gauge, or its equivalent. The top surface shall be troweled to a smooth, hard finish and, where required, true to grade.

17.8.2 The construction of the protection course shall follow the waterproofing so closely that the latter will not be exposed without protection for more than 24 hours.

17.9 MEASUREMENT AND PAYMENT

17.9.1 Payment for waterproofing shall include the cost of furnishing all equipment, materials, and labor necessary for the satisfactory completion of the waterproofing membrane and the protection course.

17.9.2 Payment will be made on the basis of the number of square yards of waterproofing complete in place.

SECTION 18 - DAMPPROOFING

18.1 GENERAL

When specified on the plans or in the special provisions, surfaces shall be dampproofed as specified herein.

18.2 MATERIALS

18.2.1 The material used for dampproofing shall be tar or asphalt as required by the special provisions.

18.2.2 Tar for absorptive treatment (or primer), tar seal coat, and asphalt for primer and seal coat shall conform to the requirements of Article 17.2.

18.3 PREPARATION OF SURFACE

The surface to which the dampproofing coating is to be applied shall be cleaned of all loose and foreign material and dirt and shall be dry. When necessary the Engineer may require the surface to be scrubbed with water and a stiff brush, after which the surface shall be allowed to dry before application of the primer.

18.4 APPLICATION

18.4.1 Concrete, brick, or other surfaces which are to be protected by dampproofing shall be thoroughly clean before the primer is applied. They shall then be brush or spray painted with two or more coats (as indicated on the plans or in the special provisions) of tar or asphalt for absorptive treatment. Below ground not less than two coats shall be applied, using 1/8 gallon for each square yard of surface. On the well-primed surface one application of tar or asphalt seal coat shall be applied by brush, using 1/10 gallon per square yard.

18.4.2 Care shall be taken to confine all paints to the areas to be waterproofed and to prevent disfigurement of any other parts of the structure by dripping or spreading of the tar or asphalt.

18.5 MEASUREMENT AND PAYMENT

18.5.1 Payment for dampproofing shall include the cost of furnishing all equipment, materials, and labor necessary for the satisfactory completion of the work.

18.5.2 Payment will be made on the basis of the number of square yards of dampproofing complete in place.

SECTION 19 - NAME PLATES

19.1 GENERAL REQUIREMENTS

19.1.1 When specified, the Contractor for the superstructure shall furnish and install name plates of such form, dimensions, material, and design as may be shown on the plans. Unless otherwise provided, the contract price for the superstructure shall include the cost of such name plates.

19.1.2 No permanent plates or markers other than those shown on the plans or approved by the Engineer will be permitted on any structure.

SECTION 20 - TIMBER STRUCTURES

20.1 MATERIALS

20.1.1 LUMBER AND TIMBER (Solid Sawn or Glued Laminated)

20.1.1.1 Sawn lumber and timber shall conform to the Specifications for Structural Timber, Lumber, and Piling, AASHTO M 168.

20.1.1.2 Structural glued laminated timber shall conform to NBS Voluntary Product Standard PS 56 for Structural Glued Laminated Timber. The term structural glued laminated timber as employed in PS 56, is an engineered stress-rated product of a timber laminating plant, comprising assemblies of suitably selected and prepared wood laminations securely bonded together with adhesives. The grain of all laminations is approximately parallel longitudinally. The separate laminations may not exceed 2 inches in net thickness. They may be comprised of pieces end joined to form any length, of pieces placed or glued edge to edge to make wider ones, or of pieces bent to curved form during gluing.

20.1.1.3 For the various structural purposes, appropriate grades, or their equivalent shall be selected in accordance with the design requirements for stress-grades given in Division 1, Section 13.

20.1.1 4 Structural lumber and timber, solid sawn or glued laminated, shall not be used in exposed permanent structures without pressure preservative treatment. Temporary structures or lumber and timber with adequate heartwood requirements (see AASHTO M 168) need not require preservatively treated lumber and timber.

20.1.2 STRUCTURAL SHAPES

Rods, plates, and shapes shall be of structural steel, as specified, conforming to the requirements of Article 10.3. Eyebars shall conform to the requirements of Article 10.3.1.2.2.

20.1.3 CASTINGS

Castings shall be cast steel or gray-iron, as specified, conforming to the requirements of Article 10.3.3 or 10.3.4.

20.1.4 HARDWARE

20.1.4.1 Machine bolts, drift-bolts, and dowels may be medium steel. Washers may be cast iron ogee or malleable iron castings, or they may be cut from medium steel plate, as specified.

20.1.4.2 Machine bolts shall have square heads and nuts, unless otherwise specified. Nails shall be cut or round wire of standard form. Spikes shall be cut or wire spikes, or boat spikes, as specified.

20.1.4.3 Nails, spikes, bolts, dowels, washers, and lag screws shall be black or galvanized, as specified.

20.1.4.4 Unless otherwise specified, all hardware for treated timber bridges, except malleable iron connectors, shall be galvanized or cadmium plated.

20.1.5 PAINT FOR TIMBER STRUCTURES

20.1.5.1 Paint for timber structures, except as otherwise provided herein, shall conform to the Specification for White and Tinted Ready-Mixed Paint, AASHTO M 70. 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 pint per gallon of the paint as specified. The paint shall be either white or tinted as directed by the Engineer.

20.1.5.2 If aluminum or black paint is specified, the first or prime coat shall be as specified above. The paint for additional coats shall be as follows:

20.1.5.2.1 ALUMINUM PAINT

(a) Aluminum paint shall conform to the Specification for Aluminum Paint, AASHTO M 69.

20.1.5.2.2 BLACK PAINT

(a) Composition

	Maximum Percent	Minimum Percent
Pigment	32	28
Liquid (containing at least 80 percent linseed oil)	72	68
Water	0.5	--
Coarse particles and "skins" (total residue retained on No. 325 sieve based on pigment)	1.5	--
Weight not less than 9.0 pounds per gallon		

(b) Pigment

The pigment in both semipaste and ready-mixed paints shall consist of carbon, lead oxide, insoluble mineral material, and, at the option of the manufacturer, oxide of iron. The pigment shall show, on analysis, not less than 20 percent of carbon and not less than 5 percent of lead oxide calculated as Pb_3O_4. (Since oxide of lead may be dissolved by the oil in paint, in all cases when the amount of lead in the pigment calculated as Pb_3O_4 is found to be less than 5 percent of the pigment, lead should be determined in the vehicle and the total lead in the paint computed to percentage of pigment.) The total of the lead oxide, iron oxide, insoluble mineral material, and loss on ignition shall be not less than 90 percent.

(c) Vehicle

The liquid in semipaste paint shall be entirely linseed oil; in ready-mixed paint it shall contain not less than 80 percent of linseed oil, the balance to be combined drier and thinner. The thinner shall be turpentine, volatile mineral spirits, or a mixture thereof.

(d) Ready-Mixed Paint

Unless otherwise authorized by the Engineer the paint shall be "ready-mixed" (factory-mixed).

Ready-mixed paint shall be well-ground, shall not settle badly or cake in the container, shall be readily broken up with a paddle to a smooth uniform paint of good brushing consistency, and shall dry within 18 hours to a full oil gloss, without streaking, running, or sagging. The color and hiding power when specified shall be equal to those of a sample mutually agreed upon by buyer and seller.

(e) Methods of Analysis

Paint shall be analyzed in acordance with methods given in Federal Test Method Standard No. 141.

20.1.6 TIMBER CONNECTORS

20.1.6.1 GENERAL

20.1.6.1.1 Connectors for treated timber structures, except those of malleable iron, shall be galvanized in accordance with AASHTO M 111 (ASTM A 123) and shall be of the type specified in Article 20.2. (See Table 20.1 for Typical Dimensions of Timber Connectors).

Table 20.1

TYPICAL DIMENSIONS OF TIMBER CONNECTORS
(dimensions in inches)

SPLIT RINGS

	2 1/2"	4"
Split Ring:		
Inside diameter at center when closed	2.500	4.00
Thickness of metal at center	.163	.193
Depth of metal (width of ring)	.750	1.000
Groove:		
Inside Diameter	2.56	4.08
Width	.18	.21
Depth	.375	.50
Bolt Hole:		
Diameter	9/16	13/16
Washers, Standard:		
Round, cast or malleable iron, diameter	2-5/8	3
Round, medium steel (minimum):		
Diameter	1-3/8	2
Thickness	3/32	5/32
Square Plate:		
Length of side	2	3
Thickness	1/8	3/16
Projected Area:		
Portion of one ring within member, (sq. in.)	1.10	2.25

Table 20.1

SHEAR PLATES
(dimensions in inches)

	2-5/8"	2-5/8"	4"	4"
Shear Plate:				
Material	Pressed steel	Light gage	Malleable iron	Malleable iron
Diameter of plate	2.62	2.62	4.02	4.02
Diameter of bolt hole	0.81	0.81	0.81	0.94
Thickness of plate	0.172	0.12	0.20	0.20
Depth of flange	0.42	0.35	0.62	0.62
Steel Strap or Shapes for Use with Shear Plates:				
Steel straps or shapes, for use with shear plates, shall be designed in accordance with accepted engineering practices.				
Hole Diameter in Straps or Shapes for Bolts	13/16	13/16	13/16	15/16
Circular Dap - dimensions:				
A	2.63	2.63	4.03	4.03
B	----	1.07	1.55	1.55
C	0.81	0.81	0.81	0.94
D	----	0.65	0.97	0.97
E	0.19	0.13	0.27	0.27
F	0.45	0.38	0.64	0.64
G	0.25	0.14	0.22	0.22
H	----	0.34	0.50	0.50
I	2.25	2.37	3.49	3.49
Bolt Hole - diameter in timber	13/16	13/16	13/16	15/16

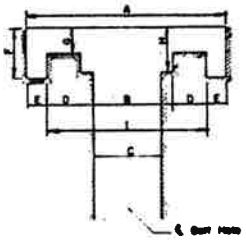


Table 20.1

SHEAR PLATES
(dimensions in inches)
(continued)

Washers, Standard:				
Round, cast or malleable iron diameter	3	3	3	3-1/2
Round, medium steel, minimum:				
Diameter	2	2	2	2-1/4
Thickness	5/32	5/32	5/32	11/64
Square plate:				
Length of side	3	3	3	3
Thickness	1/4	1/4	1/4	1/4
Projected Area:				
Portion of one shear plate within member, sq. in.	1.18	1.00	2.58	2.58

20.1.6.2 SPLIT RING CONNECTORS

20.1.6.2.1 Split rings of 2 1/2 inch inside diameter and 4-inch inside diameter shall be manufactured from hot rolled, low-carbon steel. Each ring shall form a closed true circle with the principal axis of the cross section of the ring metal parallel to the geometric axis of the ring. The metal section shall be beveled from the central portion toward the edges to a thickness less than the midsection. It shall be cut through in one place in its circumference to form a tongue and slot.

20.1.6.2.2 Connector grooves in timber shall be cut concentric with the bolt hole, shall conform to the cross-sectional shape of the rings and shall provide a snug fit. Inside groove diameter shall be larger than nominal ring diameter in order that the ring will expand slightly during installation.

20.1.6.3 SHEAR-PLATE CONNECTORS

20.1.6.3.1 PRESSED STEEL TYPE

Pressed steel shear-plates of 2 5/8 inch diameter shall be manufactured from mild steel. Each plate shall be a true circle with a flange around the edge, extending at right angles to the face of the plate and extending from one face only, the plate portion having a central bolt hole and two small perforations on opposite sides of the hole and midway from the center and circumference.

20.1.6.3.2 MALLEABLE IRON TYPE

Malleable iron shear-plates of 4 inch diameter shall be manufactured according to ASTM A 47, Grade No. 35018, for malleable iron casting. Each casting shall consist of a perforated round plate with a flange around the edge extending at right angles to the face of the plate and projecting from one face only, the plate portion having a central bolt hole reamed to size with an integral hub concentric to the bolt hole and extending from the same face as the flange.

20.1.6.4 SPIKE-GRID CONNECTORS

20.1.6.4.1 Spike-grid timber connectors shall be manufactured according to ASTM A 47, Grade No. 35018, for malleable iron casting. They shall consist of four rows of opposing spikes forming a 4 1/8 inch square grid with 16 teeth which are held in place by fillets. Fillets for the flat grid in cross section shall be diamond shaped. Fillets for the single curve grids shall be increased in depth to allow for curvature and shall maintain a thickness between the sloping faces of the fillets equal to the width of the fillet.

20.1.6.4.2 Circular grids of 3 1/4 inch diameter shall consist of 8 opposing spikes equally spaced around the outer circumference and held in place by connecting fillets around the outer diameter and radial fillets projecting to a central circular fillet which forms a bolt hole opening of 1 1/4 inch. Fillets in cross section shall be diamond shaped except that the inner circular fillet may be flattened on one side to provide for manufacturer identification.

20.2 TIMBER CONNECTORS

20.2.1 Timber connectors shall be one of the following types, as specified on the plans: the split ring, the shear plate, or the spike grid. The split ring and the shear plate shall be installed in precut grooves of dimensions as given herein or as recommended by the manufacturer. The spike grid shall be forced into the contact surfaces of the timbers joined by means of pressure equipment. All connectors of this type at a joint shall be embedded simultaneously and uniformly.

20.2.2 Fabrication of all structures using connectors shall be done prior to treatment. When prefabricated from templates or shop details, bolt holes shall not be more than 1/16 inch from required placement. Bolt holes shall be 1/16 inch larger than bolt diameter. Bolt holes shall be bored perpendicular to the face of the timber.

20.2.3 Timber after fabrication shall be stored in a manner which will prevent changes in the dimensions of the members before assembly.

20.2.4 Dimensions of material and details not otherwise specified shall meet with the approval of the Engineer.

20.3 STORAGE OF MATERIAL

20.3.1 Lumber and timber stored on the site shall be kept in orderly piles or stacks. Untreated material shall be open-stacked on supports at least 12 inches above the ground surface to avoid absorption of ground moisture and permit air circulation and it shall be so stacked and stripped as to permit free circulation of air between the tiers and courses. In particular cases required by the Engineer, the Contractor shall provide protection from the weather by a suitable covering.

20.3.2 On glued laminated structural members that are not to be preservatively treated, an approved end sealer shall be applied after end trimming of each completed member.

20.4 WORKMANSHIP

Workmanship shall be first class throughout. None but competent bridge carpenters shall be employed and all framing shall be true and exact. Unless otherwise specified, nails and spikes shall be driven with just sufficient force to set the heads flush with the surface of the wood. Deep hammer marks in wood surfaces shall be considered evidence of poor workmanship and sufficient cause for removal of the workman causing them. The workmanship on all metal parts shall conform to the requirement of Article 10.2.

20.5 TREATED TIMBER

20.5.1 HANDLING

Treated timber shall be carefully handled without sudden dropping, breaking of outer fibers, bruising, or penetrating the surface with tools. It shall be handled with rope slings. Cant hooks, peaveys, pikes, or hooks shall not be used.

20.5.2 FRAMING AND BORING

All cutting, framing, and boring of treated timbers shall be done before treatment insofar as is practicable. When treated timbers are to be placed in waters infested by marine borers, untreated cuts, borings, or other joint framings below high water elevation shall be avoided.

20.5.3 CUTS AND ABRASIONS

20.5.3.1 All cuts in treated piles or timbers, and all abrasions, after having been carefully trimmed, shall be covered with 2 applications of a mixture of 60 percent creosote oil and 40 percent roofing pitch or brush coated with at least two applications of hot creosote oil and covered with hot roofing pitch.

20.5.3.2 For field treatment of other preservatives see AWPA Standard M 4-62 entitled "Standard for the Care of Pressure Treated Wood Products."

20.5.4 BOLT HOLES

All bolt holes bored after treatment shall be treated with creosote oil by means of an approved pressure bolt hole treater. Any unfilled holes, after being treated with creosote oil, shall be plugged with creosoted plugs.

20.5.5 TEMPORARY ATTACHMENT

Whenever, with the approval of the Engineer, forms or temporary braces are attached to treated timber with nails or spikes, the holes shall be filled by driving galvanized nails or spikes flush with the surface or plugging holes as required for bolt holes.

20.6 UNTREATED TIMBER

20.6.1 In temporary structures of untreated timber the following surfaces shall be thoroughly coated with two coats of hot creosote oil before assembling: ends, tops, and all contact surfaces of sills, caps, floor beams, and stringers; and all ends, joints, and contact surfaces of bracing and truss members. The back faces of bulkheads and all other timber which is to be in contact with earth, metal, or other timber shall be similarly treated.

20.6.2 Bolts passing through non-resinous wood shall preferably be galvanized.

20.7 TREATMENT OF PILE HEADS

20.7.1 Pile heads, after cutting to receive the caps, and prior to placing the caps shall be treated to prevent decay.

20.7.2 Immediately after making final cut-off on treated timber foundation piles, the cut area shall be given two liberal applications of preservative followed by a heavy application of coal-tar pitch, or other approved sealer. Treated timber piles which will have the cut-off exposed in the structure shall have the cut area treated with three coats of a compatible preservative material meeting the requirements of AWPA Standard M4. A minimum time period of two hours shall elapse between each application.

20.8 HOLES FOR BOLTS, DOWELS, RODS, AND LAG SCREWS

20.8.1 Holes for round drift-bolts and dowels shall be bored with a bit 1/16 inch less in diameter than the bolt or dowel to be used. The diameter of holes for square drift-bolts or dowels shall be equal to the least dimension of the bolt or dowel.

20.8.2 Holes for machine bolts shall be bored with a bit the same diameter as the bolt, except as otherwise provided in Article 20.2.

20.8.3 Holes for rods shall be bored with a bit 1/16 inch greater in diameter than the rod.

20.8.4 Holes for lag screws shall be bored with a bit not larger than the body of the screw at the base of the thread.

20.9 BOLTS AND WASHERS

20.9.1 A washer, of the size and type specified, shall be used under all bolt heads (except for timber bolts with button type heads) and nuts which would otherwise come in contact with wood.

20.9.2 The nuts of all bolts shall be effectually locked after they have been finally tightened.

20.10 COUNTERSINKING

All recesses in treated timber, formed for countersinking shall be painted with hot creosote oil. Recesses likely to collect injurious materials shall be filled with hot pitch.

20.11 FRAMING

All lumber and timber shall be accurately cut and framed to a close fit in such manner that the joints will have even bearing over the entire contact surfaces. Mortises shall be true to size for their full depth and tenons shall fit snugly. No shimming will be permitted in making joints, nor will open joints be accepted.

20.12 PILE BENTS

20.12.1 The piles shall be driven as indicated on the plans, with a variation of the portion above the ground of not more than 1/4 inch per foot from the vertical or batter indicated, or so that the cap may be placed in its proper location without inducing excessive stresses in the piles. Excessive manipulation of the piles will not be permitted and the Contractor will be required to redrive or use other satisfactory methods to avoid such manipulations. No shimming on tops of piles will be permitted.

20.12.2 The piles for any one bent shall be carefully selected as to size, to avoid undue bending or distortion of the sway bracing. However, care shall be exercised in the distribution of piles of varying sizes to secure uniform strength and rigidity in the bents of any given structure.

20.12.3 Cut-offs shall be accurately made to insure perfect bearing between the cap and piles.

20.13 FRAMED BENTS

20.13.1 MUD SILLS

Untreated timber used for mud sills shall be of heart cedar, heart cypress, redwood, or other durable timber. Mud sills shall be firmly and evenly bedded to solid bearing and tamped in place.

20.13.2 CONCRETE PEDESTALS

Concrete pedestals for the support of framed bents shall be carefully finished so that the sills or posts will take even bearing on them. Dowels of not less than 3/4 inch diameter and projecting at least 6 inches above the tops of the pedestals, shall be set in them when they are cast, for anchoring the sills or posts.

20.13.3 SILLS

Sills shall have true and even bearing on mud sills, piles, or pedestals. They shall be drift-bolted to mud sills or piles with bolts of not less than 3/4 inch diameter and extending into the mud sills or piles at least 6 inches. When possible, all earth shall be removed from contact with sills so that there will be free air circulation around them.

20.13.4 POSTS

20.13.4.1 Posts shall be fastened to pedestals with dowels of not less than 3/4 inch diameter, extending at least 6 inches into the posts.

20.13.4.2 Posts shall be fastened to sills by one of the following methods, as indicated on the plans:

(a) By dowels of not less than 3/4 inch diameter, extending at least 6 inches into posts and sills.

(b) By drift-bolts of not less than 3/4 inch diameter driven diagonally through the base of the post and extending at least 9 inches into the sill.

20.13.5 DESIGN AND CONSTRUCTION

Where framed structures will be subjected to earthquake, wind, tractive, or centrifugal loads, the connections between members thereof shall be so designed and constructed as to resist the forces resulting therefrom (See Division 1, Article 3.)

20.14 CAPS

Timber caps shall be placed, with ends aligned, in a manner to secure an even and uniform bearing over the tops of the supporting posts or piles. All caps shall be secured by drift-bolts of not less than 3/4 inch diameter, extending at least 9 inches into the posts or piles. The drift-bolts shall be approximately in the center of the post or pile. (See Article 20.13.4.)

20.15 BRACING

Bracing shall be bolted through the pile, post or cap with a bolt of not less than 5/8 inch diameter at the ends and all intermediate intersections.

20.16 STRINGERS

20.16.1 Stringers shall be sized at bearings and shall be placed in position so that knots near edges will be in the top portions of the stringers.

20.16.2 Outside stringers may have butt joints with the ends cut on a taper, but interior stringers shall be lapped to take bearing over the full width of the floor beam or cap at each end. The lapped ends of untreated stringers shall be separated at least 1/2 inch for the circulation of air and shall be securely fastened by drift-bolting where specified. When stringers are two panels in length the joints shall be staggered.

20.16.3 Cross-bridging between stringers shall be neatly and accurately framed and securely toe-nailed with at least two nails in each end. All cross-bridging members shall have full bearing at each end against the sides of stringers. Unless otherwise specified in the contract, cross-bridging shall be placed at the center of each span.

20.17 PLANK FLOORS

20.17.1 Planks shall be of the grade required as specified in Article 20.1.1. Unless otherwise specified, they shall be surfaced four sides (S 4 S).

20.17.2 Single plank floors shall consist of a single thickness of plank supported by stringers or joists. The planks shall be laid heart side down, with 1/4 inch openings between them for seasoned material and with tight joints for unseasoned material. Each plank shall be securely spiked to each joist. The planks shall be carefully graded as to thickness and so laid that no two adjacent planks shall vary in thickness by more than 1/16 inch.

20.17.3 Two-ply timber floors shall consist of two layers of flooring supported on stringers or joists. The top course may be laid either diagonal or parallel to the centerline of roadway, as specified and each floor piece shall be securely fastened to the lower course. Joints shall be staggered at least 3 feet. If the top flooring is placed parallel to the centerline of the roadway, special care shall be taken to securely fasten the ends of the flooring. At each end of the bridge these members shall be beveled.

20.18 NAIL LAMINATED OR STRIP FLOORS

20.18.1 The strips shall be of the grade required as specified in Article 20.1.1. The strips shall be placed on edge, at right angles to the centerline of roadway. Each strip shall be spiked to the preceding strip at each end and at approximately 18 inch intervals with the spikes driven alternately near the top and bottom edges. The spikes shall be of sufficient length to pass through two strips and at least half-way through the third strip.

20.18.2 If timber supports are used, every other strip shall be toe-nailed to every other support. The size of the spikes shall be as shown on the plans. When specified on the plans, the strips shall be securely attached to steel supports by the use of approved galvanized metal clips. Care shall be taken to have each strip vertical and tight against the preceding one, and bearing evenly on all the supports.

20.19 COMPOSITE WOOD-CONCRETE DECKS

20.19.1 SLAB SPANS

20.19.1.1 Where the tensile strength of wood and the compressive strength of concrete are to be used compositely, the joining of the two materials shall be such as to resist all horizontal shear at that plane, and provision shall be made to prevent separation of the materials.

20.19.1.2 The horizontal shear may be resisted by metal devices set into and projecting above the top of the laminated strips, or by fabricating the upper edge of the strips in a serrated manner.

20.19.1.3 Separation of the materials may be resisted by nails driven at an angle in the upper edge of the strips, or by certain suitable devices, or by grooves or other working of upstanding strips.

20.19.2 BEAMS

20.19.2.1 Spans consisting of concrete slabs placed on wood stringers may be designed as "I" beams when the two materials are suitably joined so as to resist horizontal shear at their juncture and the materials are bonded permanently together.

20.19.2.2 A horizontal shear joint may be made using metal devices or by a serrated working of the tops of the stringers.

20.19.2.3 Separation of the concrete from the stringers may be prevented by driving nails in the top of the stringers at an angle, or by other suitable metal devices, or by grooving the sides of the stringers near the top, or other working of the wood, and then forming the concrete into the pattern worked in the wood.

20.20 WHEEL GUARDS AND RAILING

20.20.1 Wheel guards and railing shall be accurately framed in accordance with the plans and erected true to line and grade.

20.20.2 Unless otherwise specified, wheel guards, rails, and rail posts shall be surfaced four-sides (S 4 S).

20.20.3 Wheel guards shall be laid in sections not less than 12 feet long.

20.21 TRUSSES

Trusses, when completed, shall show no irregularities of line. Chords shall be straight and true from end to end in horizontal projection and, in vertical projection, shall show a smooth curve through panel points conforming to the correct camber. All bearing surfaces shall fit accurately. Uneven or rough cuts at the points of bearing shall be cause for rejection of the piece containing the defect.

20.22 TRUSS HOUSINGS

The carpentry on truss housings shall be equal in all respects to the best house carpentry. The finished appearance of the housing is considered of primary importance and special care shall be taken to secure a high quality of workmanship and finish on this portion of the structure. Workmen wearing shoes with caulks will not be permitted on the roof.

20.23 ERECTION OF HOUSING AND RAILINGS

Unless otherwise directed by the Engineer, housing and railings shall be built after the removal of the falsework and the adjustment of the trusses to correct alignment and camber.

20.24 PAINTING

20.24.1 Rails and rail posts of untreated timber, shall be painted with three coats of paint.

20.24.2 Parts of the structure, other than rails and rail posts, which are to be painted, shall be designated on the plans or in the special provisions.

20.24.3 Metal parts, except hardware, shall be given one coat of shop paint and, after erection, two coats of field paint as specified in Section 14.

20.25 MEASUREMENT AND PAYMENT

20.25.1 Payment for timber structures shall include the furnishing of materials, preservative treatment, equipment, tools, and labor necessary for the erection and painting of the work in a satisfactory manner.

20.25.2 Lumber and timber, unless otherwise specified, shall be paid for at the contract price per 1,000 feet board-measure for material remaining in the finished structure, including the cost of all hardware. Computations of the amount of lumber and timber in the structure shall be based on nominal sizes and the shortest commercial length which could be used. No other allowance for waste will be made.

20.25.3 Metal parts, other than hardware, shall be paid for at the contract price per pound, the weight being computed in the same manner as specified for steel structures, Article 10.54.

SECTION 21 - PRESERVATIVE TREATMENTS FOR TIMBER

21.1 GENERAL

21.1.1 The kind of preservative treatment required shall be as specified in the special provisions or as noted on the plans.

21.1.2 The preservatives specified herein are not intended to be used interchangeably, but the kind of preservative to be used shall be adopted for its suitability to the conditions of exposure to which it will be subjected. Some of the conditions to be considered are: effect of marine borers, effect of termites, action of exposure to water and leaching of the preservative, effect of contact with the ground, painting requirements, and cleanliness requirements. Experience records for the particular exposure intended shall be given consideration in selecting the treatment to be used.

21.2 MATERIALS

21.2.1 Piling shall conform to the requirements of AASHTO M 168. Timber and lumber shall conform to the requirements of AASHTO M 168. Only wood species for which treatment requirements are listed in AASHTO M 133 may be specified. All wood species so listed are not equally treatable and therefore all species are not equally acceptable under severe exposure conditions. Care should be exercised to select those species in AASHTO M 133 which are acceptable for the intended application.

21.2.2 Timber preservatives and treatment method shall conform to AASHTO M 133. The type of preservative furnished shall be in accordance with that specified in the special provisions or as noted on the plans. When selecting a preservative and a preservative retention, it should be noted that AASHTO M 133 designates the preservatives and retentions recommended for Coastal Waters and in marine structures and further that timber for use in "ground or water contact" has requirements that differ from timbers for use "not in ground or water contact." In some instances there is a range of retentions offered which provides for different degrees of exposure based on climate or degree of insect infestation. Unless the higher retentions are specified, not less than the minimum retention is required.

21.2.2 Timbers expected to be painted should be treated with waterborne salts or pentachloropheno carried in a volatile organic solvent.

21.3 IDENTIFICATION AND INSPECTION

Each piece of treated timber shall bear a legible brand, mark, or tag indicating the name of the treater and the specification symbol or specification requirements to which the treatment conforms. The Engineer shall be provided adequate facilities and free access to the necessary parts of the treating plant for inspection of material and workmanship to determine that the contract requirements are met. The Engineer reserves

the right to retest all materials after delivery to the job site and to reject all materials which do not meet the requirements of the contract; provided that, at the job site reinspection, conformance within five percent of contract requirements shall be acceptable. Reinspection at the job site may include assay to determine retention of preservatives and extraction and analysis of preservative to determine its quality.

SECTION 22 - TIMBER CRIBBING

22.1 MATERIAL

22.1.1 TIMBER

Timber used for cribbing shall conform to the requirements of Section 20.1, and unless otherwise specified shall be the same as for caps, posts, sills, etc. If treated timber is used, all hardware shall be galvanized or cadmium plated.

22.1.2 LOGS

Logs used for cribbing shall conform in quality to the requirements specified for timber piles in AASHTO M 168.

22.2 PREPARATION

22.2.1 When timber or logs are to be treated, all framing shall be completed before treatment and all surfaces cleaned of dirt and grease.

22.2.2 All timber and log framing shall be done in a workmanlike manner and true to line and angle.

22.3 DIMENSIONS

22.3.1 TIMBER

When cribs are constructed of sawed timber, no timber shall be less than 8 inches in least dimension. The face timber in the base tier shall be not less than 10 inches in least dimension.

22.3.2 LOGS

22.3.2.1 When cribs are constructed of logs, no face log shall have a diameter at the small end of less than 10 inches and tie logs shall be not less than 8 inches in diameter at the small end. The face log in the base tier shall be not less than 12 inches in diameter at the small end.

22.3.2.2 All logs for cribbing shall be selected from the logs available with as small an amount of taper as possible. The length of logs used shall be somewhat dependent upon the taper.

22.4 CONSTRUCTION

22.4.1 FOUNDATION

The foundation or bed for the cribbing shall be excavated to exact grade and shall be approved as to bearing quality by the Engineer before any of the crib work is placed.

22.4.2 MUD SILLS

22.4.2.1 When mud sills are used, they shall be set at right angles to the face of the cribbing, and firmly and evenly bedded in the foundation material.

22.4.2.2 Mud sills shall be not less than 12 by 12 inches in squared cross-sectional dimensions and not less than 3 feet in length. They shall be spaced not more than 4 feet apart.

22.4.2.3 Log or timber mud sills shall be leveled to fit the first tier resting upon them. In no case shall there be less than 100 square inches of flat contact surface between the face log and each mud sill.

22.4.2.4 Foundation materials shall be thoroughly tamped around all mud sills.

22.4.3 FACE LOGS OR TIMBERS

22.4.3.1 The logs or timbers in the base tier and in alternate tiers above the base shall be as long as practicable and preferably, shall extend the full length of the face. In intermediate tiers they may have a length of not less than 8 feet arranged to break joints. Crib faces shall be laid solid or with spacers as indicated on the plans.

22.4.3.2 All framed surfaces shall receive a heavy coat of approved preservative at the time of assembling.

22.4.3.3 Care shall be exercised in the erection of all cribs to produce a true face as shown on the plans. All timbers or logs in faces shall be horizontal.

22.4.4 TIES

22.4.4.1 The length of ties shall be sufficient to develop the required anchorage against overturning, and in no case shall the length of tie extending into the fill be less than two-thirds of the height of fill above the tie in question.

22.4.4.2 Ties shall be anchored to the face walls by framing, either dovetailed or by sufficient projection beyond the face of the crib to form the proper anchorage. Ties shall be anchored at the fill end to cross pieces fastened to them at right angles by drift-bolts or other suitable means.

22.4.4.3 Ties shall be spaced not more than 8 feet center to center in any horizontal tier and shall be staggered with the next adjacent tier of ties. Tiers of ties shall be not more than 3 feet apart vertically.

22.4.5 FASTENING

22.4.5.1 Each successive tier of logs or timbers shall be drift-bolted to the one upon which it rests by drifts not less than 3/4 inches in diameter and of sufficient length to extend through 2 tiers and not less than 4 inches into the third tier.

22.4.5.2 Drift-bolts shall be staggered and not more than 8 feet center to center in each tier.

22.4.5.3 All end joints and splices shall be half-lapped for 10 inches and drifted at the center.

22.4.5.4 Before assembling, all framed joints in contact shall be heavily coated with an approved preservative.

22.5 FILLING

Filling inside and around cribs shall be of the material specified and shall be placed in a careful manner so as to avoid distortion of the crib. Filling shall be placed in even horizontal layers and compacted to reduce the voids to a minimum.

22.6 MEASUREMENT AND PAYMENT

22.6.1 Payment for the construction of cribbing shall include the furnishing of all materials, equipment, tools, and labor necessary for the excavation, crib erection, and filling, complete in place, in accordance with the plans and these specifications. Payment for timber and logs shall include the cost of drift-bolts and other miscellaneous hardware.

22.6.2 Excavation for cribbing shall be paid for at the contract price per cubic yard for material actually removed except that in no case shall this be computed to include material more than 1 foot outside of vertical planes through the extreme neat lines of the finished crib or its supports. The contract price for excavation shall include a quantity of backfill equivalent to that excavated between the neat lines and the pay lines.

22.6.3 Timber shall be paid for at the contract price per 1,000 feet board-measure for material remaining in the finished structure.

22.6.4 Logs shall be paid for at the contract price per linear foot, for each size specified, for material remaining in the finished structure.

22.6.5 Filling material shall be paid for at the contract price per cubic yard for the actual volume placed.

SECTION 23 - CONSTRUCTION AND INSTALLATION OF SOIL METAL PLATE STRUCTURE INTERACTION SYSTEMS

23.1 GENERAL

23.1.1 This item shall consist of furnishing corrugated metal or structural plate pipe, pipe-arches, and arches conforming to these specifications and of the sizes and dimensions required on the plans, and installing such structures at the places designated on the plans or by the Engineer, and in conformity with the lines and grades established by the Engineer. Pipe shall be either ciruclar or elongated as specified or shown on the plans.

23.1.2 The thickness of plates or sheets shall be as determined in Article 12.2, Division 1, and the radius of curvature shall be as shown on the plans. Each plate or sheet shall be curved to one or more circular arcs.

23.1.3 The plates at longitudinal and circumferential seams of structural plates shall be connected by bolts. Joints shall be staggered so that not more than three plates come together at any one point.

23.2 FORMING AND PUNCHING OF CORRUGATED STRUCTURAL PLATES AND SHEETS FOR PIPE

23.2.1 STRUCTURAL PLATE PIPE

23.2.1.1 Structural plates of steel shall conform to the requirements of AASHTO M 167 and aluminum to the requirements of AASHTO M 219.

23.2.1.2 Plates shall be formed to provide lap joints. The bolt holes shall be so punched that all plates having like dimensions, curvature, and the same number of bolts per foot of seam shall be interchangeable. Each plate shall be curved to the proper radius so that the cross-sectional dimensions of the finished structure will be as indicated on the drawings or as specified.

23.2.1.3 Unless otherwise specified, bolt holes along those edges of the plates that form longitudinal seams in the finished structure shall be in two rows. Bolt holes along those edges of the plates that form circumferential seams in the finished structure shall provide for a bolt spacing of not more than 12 inches. The minimum distance from center of hole to edge of the plate shall be not less than 1 3/4 times the diameter of the bolt. The diameter of the bolt holes in the longitudinal seams shall not exceed the diameter of the bolt by more than 1/8 inch.

23.2.1.4 Plates for forming skewed or sloped ends shall be cut so as to give the angle of skew or slope specified. Burned edges shall be free from oxide and burrs and shall present a workmanlike finish. Legible identification numerals shall be placed on each plate to designate its proper position in the finished structure.

23.2.2 CORRUGATED METAL PIPE

23.2.2.1 Corrugated steel pipe shall conform to the requirements of AASHTO M 36 and aluminum to the requirements of AASHTO M 196.

23.2.2.2 Punching and forming of sheets shall conform to AASHTO M 36.

23.2.3 ELONGATION

If elongated structural plate or corrugated metal pipe is specified or called for on the plans, the plates or pipes shall be formed so that the finished pipe is elliptical in shape with the vertical diameter approximately five percent greater than the nominal diameter of the pipe. Pipe-arches shall not be elongated. Elongated pipes shall be installed with the longer axis vertical.

23.3 ASSEMBLY

23.3.1 GENERAL

23.3.1.1 Corrugated metal pipe and structural plate pipe shall be assembled in accordance with the manufacturer's instructions. All pipe 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 trench or on bedding.

23.3.1.2 Corrugated metal pipe shall be placed on the bed starting at downstream end with the inside circumferential laps pointing downstream.

23.3.1.3 Bituminous 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.

23.3.1.4 Structural plate pipe, pipe arches, and arches shall be installed in accordance with the plans and detailed erection instructions. Bolted longitudinal seams shall be well fitted with the lapping plates parallel to each other. The applied bolt torque for 3/4" diameter high-strength steel bolts shall be a minimum of 100 ft.-lbs. and a maximum of 300 ft.-lbs. for 3/4" diameter aluminum bolts, the applied bolt torque shall be a minimum of 100 ft.-lbs. and a maximum of 150 ft.-lbs. There is no structural requirement for residual torque; the important factor is the seam fit-up.

23.3.1.5 Joints for corrugated metal culvert and drainage pipe shall meet the following performance requirements:

23.3.1.5.1 FIELD JOINTS

Transverse field joints shall be of such design that the successive connection of pipe sections will form a continuous line free from appreciable irregularities in the flow line. In addition, the joints shall meet the general performance requirements described in items 23.3.1.5.1 through 23.3.1.5.3. Suitable transverse field joints, which satisfy the requirements for one or more of the subsequently defined joint performance categories can be obtained with the following types of connecting bands furnished with the suitable band-end fastening devices.

(a) Corrugated bands

(b) Bands with projections

(c) Flat bands

(d) Bands of special design that engage factory reformed ends of corrugated pipe.

(e) Other equally effective types of field joints may be used with the approval of the Engineer.

23.3.1.5.2 JOINT TYPES

Applications may require either "Standard" or "Special" joints. Standard joints are for pipe not subject to large soil movements or disjointing forces, these joints are satisfactory for ordinary installations, where simple slip type joints are typically used. Special joints are for more adverse requirements such as the need to withstand soil movements or resist disjointing forces. Special designs must be considered for unusual conditions as in poor foundation conditions. Downdrain joints are required to resist longitudinal hydraulic forces. Examples of this are steep slopes and sharp curves.

23.3.1.5.3 SOIL CONDITIONS

(a) The requirements of the joints are dependent upon the soil conditions at the construction site. Pipe backfill which is not subject to piping action is classified as "Nonerodible." Such backfill typically includes granular soil (with grain sizes equivalent to coarse sand, small gravel, or larger) and cohesive clays.

(b) Backfill that is subject to piping action, and would tend either to infiltrate the pipe to be easily washed by exfiltration of water from the pipe, is classified as "Erodible". Such backfill typically includes fine sands and silts.

(c) Special joints are required when poor soil conditions are encountered such as when the backfill or foundation material is characterized by large soft spots or voids. If construction in such soil is unavoidable, this condition can only be tolerated for relatively low fill heights, since the pipe must span the soft spots and support imposed loads. Backfills of organic silt, which are typically semifluid during installation, are included in this classification.

23.3.1.5.4 JOINT PROPERTIES

The requirements for joint properties are divided into the six categories shown on Table 23.3. Properties are defined and requirements are given in the following Paragraphs (a) through (f). The values for various types of pipe can be determined by a rational analysis or a suitable test.

(a) Shear Strength - The shear strength required of the joint is expressed as a percent of the calculated shear strength of the pipe on a transverse cross section remote from the joint.

(b) Moment Strength - The moment strength required of the joint is expressed as a percent of the calculated moment capacity of the pipe on a transverse cross section remote from the joint.

(c) Tensile Strength - Tensile strength is required in a joint when the possibility exists that a longitudinal load could develop which would tend to separate adjacent pipe section.

(d) 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 shown in Table 23.3. Any joint meeting the requirements for a special joint may be used in lieu of a standard joint.

(e) Soiltightness - Soiltightness refers to openings in the joint through which soil may infiltrate. Soil tightness is influenced by the size of the opening (maximum dimension normal to the direction that the soil may infiltrate) and the length of the channel (length of the path along which the soil may infiltrate). No opening may exceed 1 inch. In addition, for all categories, if the size of the opening exceeds 1/8 inch, the length of the channel must be at least four times the size of the opening. Furthermore, for nonerodible or erodible

Table 23.3

CATEGORIES OF PIPE JOINTS

	Soil Condition				Downdrain
	Non-Erodible Joint Type		Erodible Joint Type		
	Standard	Special	Standard	Special	
Shear	2%	5%	2%	5%	2%
Moment[a]	5%	15%	5%	15%	15%
Tensile 0.42" diameter	0	5,000 lbs.	--	5,000 lbs.	5,000 lbs.
48" - 84" diameter	--	10,000 lbs.	--	10,000 lbs.	10,000 lbs.
Joint Overlap[c] (Min.)	10 1/2"	NA	10 1/2"	NA	NA
Soiltightness[b]	NA	NA	0.3 or 0.2	0.3 or 0.2	0.3 or 0.2
Watertightness	See Paragraph 1.5.4(f)				

[a]See Paragraph 23.3.1.5.4(b).

[b]Minimum Ratio of D_{85} soil size to size of opening 0.3 for medium to fine sand and 0.2 for uniform sand.

[c]Alternate requirement. See Article 23.3.1.5.4(e).

Structural plate pipe, pipe-arches, and arches shall be installed in accordance with the plans and detailed erection instructions.

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 12. As a general guideline, a backfill material containing a high percentage of fine grained soils requires investigation for the specific type of joint to be used to guard against soil infiltration. Alternatively, if a joint demonstrates its ability to pass a 2 psi hydrostatic test without leakage, it will be considered soil tight.

(f) Watertightness - 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 adjoining pipe ends in any joint shall not vary more than 0.5 inch in diameter or more than 1.5 inches in circumference for watertight joints. These tolerances may be attained by proper production controls or by match-marking pipe ends.

23.3.2 ASSEMBLY OF LONG-SPAN STRUCTURES

Long-span structures covered in Article 12.6 may require deviation from the normal good practice of loose bolt assembly. Unless held in shape by cables, struts, or backfill, longitudinal seams should be tightened when the plates are hung. Care should be taken to properly align plates circumferentially and to avoid permanent distortion from specified shape. This may require temporary shoring. The variation before backfill shall not exceed 2 percent of the span or rise, whichever is greater, but in no case shall exceed 5 inches. The rise of arches with a ratio of top to side radii of three or more should not deviate from the specified dimensions by more than 1 percent of the span.

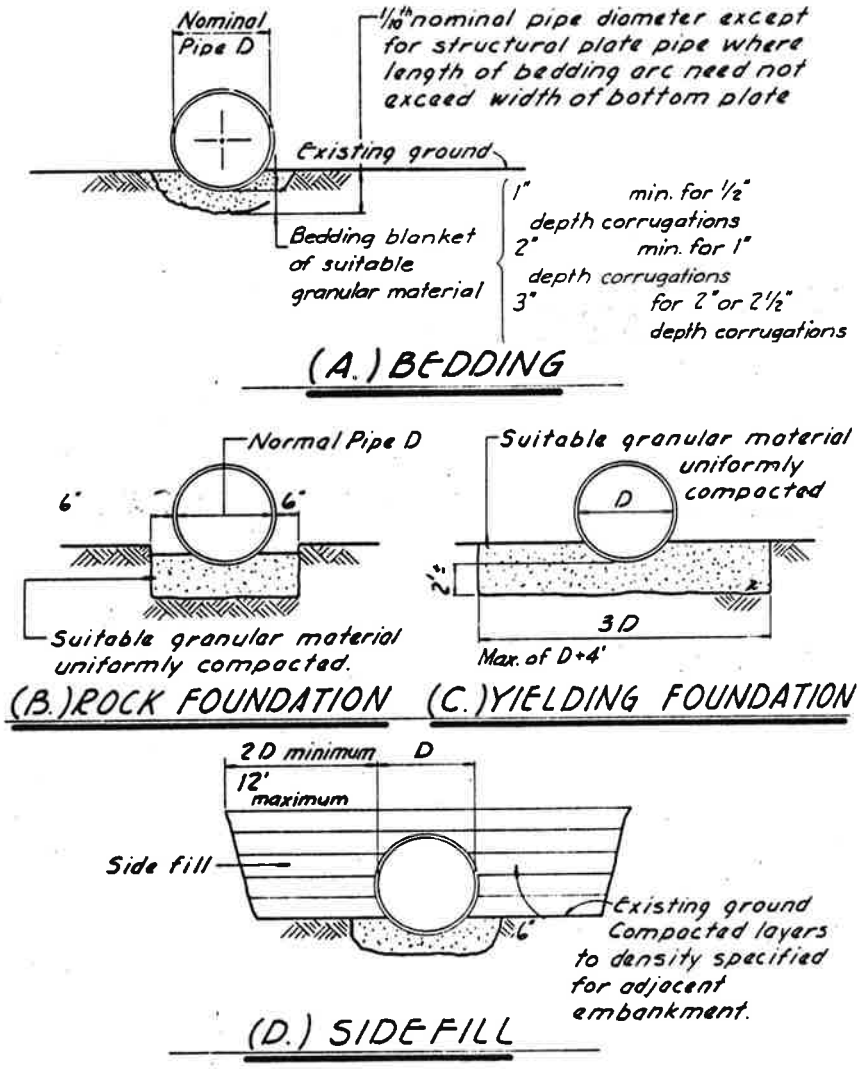
23.4 BEDDING

23.4.1 When, in the opinion of the Engineer, the natural soil does not provide a suitable bedding, a bedding blanket conforming to Figure 23.4A shall be provided. Bedding shall be uniform for the full length of the pipe.

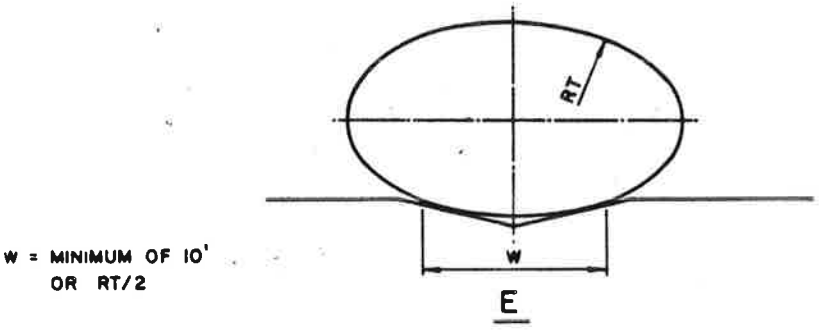
23.4.2 Bedding of long-span structures with invert plates exceeding 12 ft. in radius requires a preshaped excavation or bedding blanket for a minimum width of 10 ft. or half the top radius of the structure, whichever is less. This preshaping may be a simple "v" shape fine graded in the soil in accordance with Figure 23.4E.

23.5 PIPE FOUNDATION

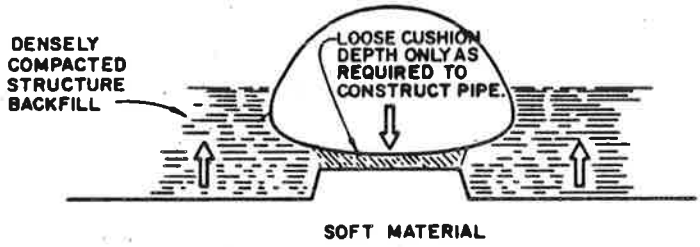
23.5.1 The foundation material under the pipe shall be investigated for its ability to support the load. If rock strata or boulders are

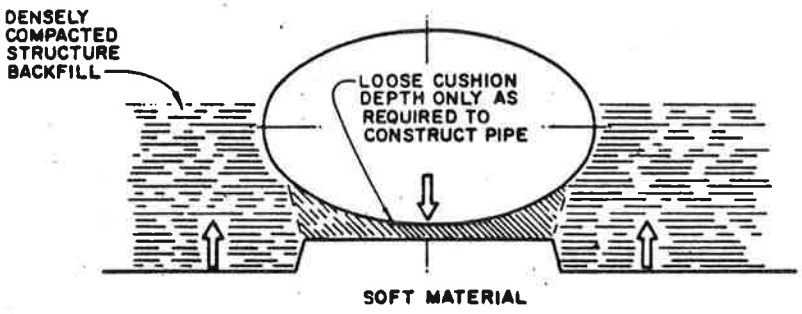


Figures 23.4 A, B, C and D



E





DIFFERENTIAL EXCAVATION REQUIRED AS SHOWN TO INSURE PROPER RELATIVE MOTION AS INDICATED BY ARROWS. IF ENTIRE FOUNDATION IS OVER EXCAVATED AREA UNDER LARGE RADIUS INVERT PLATES SHALL NOT BE COMPACTED AS DENSELY AS UNDER CORNERS OR SIDES TO PROVIDE RELATIVE YIELDING OF INVERT COMPARED TO CORNERS OR SIDES

F

Figures 23.4 E and F

closer than 12 inches under the pipe, the rock or boulders shall be removed and replaced with suitable granular material as shown in Figure 23.4B. 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 suitable granular material as shown in Figure 23.4C. Where an unsuitable material (peat, muck, etc) 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.

23.5.2 For shapes such as pipe arches, horizontal ellipses, or underpasses, where relatively large radius inverts are joined by relatively small radius corners or sides, the corrective treatment shall provide for principal support of the structure at the adjoining corner or side plates and insure proper settlement of those high pressure zones relative to the low pressure zone under the invert, as shown in Figure 23.4F. This allows the invert to settle uniformly.

23.6 FILL REQUIREMENTS

23.6.1 SIDEFILL

23.6.1.1 Sidefill material within one pipe diameter of the sides of pipe and not less than one foot over the pipe shall be fine readily compactible soil or granular fill material. Sidefill beyond these limits may be regular embankment fill. Job-excavated soil used as backfill shall not contain stones retained on a 3 inch ring, frozen lumps, chunks of highly plastic clay, or other objectionable material. Sidefill material shall be noncorrosive.

23.6.1.2 Sidefill material shall be placed as shown in Figure 23D, in layers not exceeding 6 inches in compacted thickness at near optimum moisture content by engineer-approved equipment to the density required for superimposed embankment fill. Other approved compacting equipment may be used for sidefill more than 3 feet from sides of pipe. The sidefill shall be placed and compacted with care under the haunches of the pipe and shall be brought up evenly and simultaneously on both sides of the pipe to not less than 1 foot above the top for the full length of the pipe. Fill above this elevation may be material for embankment fill. The width of trench shall be kept to the minimum width required for placing pipe, placing adequate bedding and sidefill, and safe working conditions. Ponding or jetting of sidefill will not be permitted except upon written permission by the Engineer.

23.6.2 BACKFILL FOR LONG-SPAN STRUCTURES

While basic backfill requirements for long-span structural-plate structures are similar to those for smaller structures, their size is such that excellent control of soil placement and compaction must be maintained. Because these structures are especially designed to fully mobilize soil-structure interaction, a large portion of their full strength is not realized until backfill (sidefill and overfill) is in

place. Of particular importance is control of structure shape. Equipment and construction procedures used 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 construction inspector to aid the Engineer during all structure backfilling. The Inspector shall advise the 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 8 inches in thickness after compaction and shall be brought up uniformly on both sides of the structure. Each layer shall be compacted to a density not less than 90 percent per AASHTO T 180. The structure backfill shall be constructed to the minimum lines and grades shown on the plans, keeping it at or below the level of adjacent soil. Permissible exceptions to required structure backfill density are: the area under the invert, the 12 inch to 18 inch 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 heavy construction earth movers initially crossing the structure.

23.7 BRACING

23.7.1 Temporary bracing shall be installed and shall remain in place as required to protect workmen during construction.

23.7.2 For long-span structures which require temporary bracing to handle backfilling loads, the bracing shall not be removed until the fill is completed or to a height over the crown equal to 1/4 the span.

23.8 CAMBER

23.8.1 The invert grade of the pipe shall be cambered, when required, by an amount sufficient to prevent the development of a sag or back slope in the flow line as the foundation under the pipe settles under the weight of embankment. The amount of camber shall be based on consideration of the flow-line gradient, height of fill, compressive characteristics of the supporting soil, and depth of supporting soil stratum to rock.

23.8.2 When specified on the plans, long-span structures shall be vertically elongated approximately 2 percent during installation to provide for compression of the backfill under higher fills.

23.9 ARCH SUBSTRUCTURES AND HEADWALLS

23.9.1 Substructures and headwalls shall be designed in accordance with the requirements of Division I.

23.9.2 Each side of each arch shall rest in a groove formed into the masonry or shall rest on a galvanized angle or channel securely anchored to or embedded in the substructure. Where the span of the

arch is greater than 15 feet or the skew angle is more than 20 degrees, a metal bearing surface, having a width of at least equal to the depth of the corrugation, shall be provided for all arches.

23.9.3 Metal bearings may be either rolled structural or cold formed galvanized angles or channels, not less than 3/16 inch in thickness with the horizontal leg securely anchored to the substructure on a maximum of 24 inch centers. When the metal bearing is not embedded in a groove in the substructure, one vertical leg should be punched to allow bolting to the bottom row of plates.

23.9.4 Where an invert slab is provided which is not integral with the arch footing, the invert slab shall be continuously reinforced.

23.9.5 When backfilling arches before headwalls are placed, the first material shall be placed midway between the ends of the arch, forming as narrow a ramp as possible until the top of the arch is reached. The ramp shall be built evenly from both sides and the backfilling material shall be thoroughly compacted as it is placed. After the two ramps have been built to depth specified to the top of the arch, the remainder of the backfill shall be deposited from the top of the arch both ways from the center to the ends, and as evenly as possible on both sides of the arch.

23.9.6 If the headwalls are built before the arch is backfilled, the filling material shall first be placed adjacent to one headwall, until the top of the arch is reached, after which the fill shall be dumped from the top of the arch toward the other headwall, with care being taken to deposit the material evenly on both sides of the arch.

23.9.7 In multiple installations the procedure above specified shall be followed, but extreme care shall be used to bring the backfill up evenly on each side of each arch so that unequal pressure will be avoided.

23.9.8 In all cases the filling material shall be thoroughly but not excessively tamped. Puddling the backfill will not be permitted.

23.10 COVER OVER PIPE DURING CONSTRUCTION

All pipe shall be protected by sufficient cover before permitting heavy construction equipment to pass over them during construction.

23.11 WORKMANSHIP AND INSPECTION

In addition to compliance with the details of construction, the completed structure shall show careful finished workmanship in all particulars. Structures on which the speller coating has been bruised or broken either in the shop or in shipping, or which shows defective workmanship, shall be rejected unless repaired to the satisfaction of the Engineer. The following defects are specified as constituting poor workmanship and the presence

of any or all of them in any individual culvert plate or in general in any shipment shall constitute sufficient cause for rejection unless repaired:

(a) Uneven laps
(b) Elliptical shaping (unless specified).
(c) Variation from specified alignment.
(d) Ragged edges.
(e) Loose, unevenly lined or spaced bolts.
(f) Illegible brand.
(g) Bruised, scaled, or broken spelter coating.
(h) Dents or bends in the metal itself.

23.12 METHOD OF MEASUREMENT

Corrugated metal and structural plate pipe, pipe-arches, or arches shall be measured in linear feet installed in place, completed, and accepted. The number of linear feet shall be the average of the top and bottom centerline lengths for pipe, the bottom centerline length for pipe-arches, and the average of springing line lengths for arches.

23.13 BASIS OF PAYMENT

The lengths, determined as herein given, shall be paid for at the contract unit prices per linear foot bid for corrugated metal and structural plate pipe, pipe-arch or arches of the several sizes, as the case may be, which prices and payments shall constitute full compensation for furnishing, handling, erecting, and installing the pipe, pipe-arches, or arches and for all materials, labor, equipment, tools, and incidentals necessary to complete this item, but for arches shall not constitute payment for concrete or masonry headwalls and foundations, or for excavation.

SECTION 24 - WEARING SURFACES

24.1 DESCRIPTION

Separate wearing surfaces, when required, shall conform to details shown on the plans, and construction shall conform to that specified on the plans or in the special provisions.

24.2 ORTHOTROPIC-DECK SUPERSTRUCTURES

24.2.1 MATERIAL

The Engineer shall specify or approve the wearing surface materials. The material shall be of uniform quality and void of foreign matter.

24.2.2 PLACEMENT

24.2.2.1 Careful and competent workmen shall be used in preparing and placing the wearing surface. The wearing surface preferably shall be placed in two courses to assure a smooth riding surface. The Engineer shall specify or approve the methods of cleaning and preparing the deck, applying the bond and tack coats, grading the aggregate, measuring the proportions, mixing the ingredients, regulating the temperatures, placing and compacting the material, and selecting suitable atmospheric conditions for the work.

24.2.2.2 Prior to placement, the surface of the deck shall be thoroughly cleaned to ensure the complete removal of all mill scale, dirt, debris, oil, grease, salt, and moisture. Air, water vapor, and other gases shall not be entrapped in or under the wearing surface.

24.2.3 INSPECTION

The Engineer shall observe the manufacture and placement of the wearing surface to assure that all requirements of Subsection 24.2.2 are met. The Engineer shall specify or approve suitable control tests to establish the acceptability of the wearing surface.

SECTION 25 - ELASTOMERIC BEARINGS

25.1 DESCRIPTION

Elastomeric bearings as herein specified shall include plain bearings (consisting of elastomer only) and laminated bearings (consisting of layers of elastomer restrained at their interfaces by bonded laminates).

25.2 MATERIALS

25.2.1 The elastomer portion of the elastomeric compound shall be 100 percent virgin natural polyisoprene (natural rubber) meeting the requirements of Table A or 100 percent virgin chloroprene (neoprene) meeting the requirements of Table B, as specified by the Engineer. Compounds of nominal hardness between the values shown may be used and the test requirements interpolated. When test specimens are cut from the finished product a 10 percent variation in "Physical Properties" will be allowed.

25.2.2 Laminates shall be rolled mild steel sheets conforming to ASTM A570, Grade 36 or ASTM A611, Grade D unless otherwise specified by the Engineer.

25.3 MANUFACTURING REQUIREMENTS

Plain bearings may be molded individually, cut from previously molded strip or slabs, or extruded and cut to length. Cut edges shall be at least as smooth as ANSI 250 finish. Unless otherwise shown on the plans, all components of a laminated bearing shall be molded together into an integral unit, and all edges of the nonelastic laminations shall be covered by a minimum of 1/8 inch of elastomer except at laminate restraining devices and around holes that will be entirely closed on the finished structure.

25.4 TOLERANCES

25.4.1 Flash tolerance, finish and appearance shall meet the requirements of the latest edition of the Rubber Handbook as published by the Rubber Manufacturers Association, Inc., RMA F3 and T.063 for moulded bearings and RMA F2 for extruded bearings.

25.4.2 For both plain and laminated bearings, the permissible variation from the dimensions and configuration required by the plans and these specifications shall be as follows:

(a) Overall Vertical Dimensions	
Average Total Thickness 1 1/4" or less	-0, +1/8"
Average Total Thickness over 1 1/4"	-0, +1/4"
(b) Overall Horizontal Dimension	
36" and less	-0, +1/4"
over 36"	-0, +1/2"

TABLE A

ASTM Standard		50 Duro	60 Duro	70 Duro
PHYSICAL PROPERTIES				
D2240	Hardness	50+5	60+5	70+5
D412	Tensile strength, minimum psi	2,500	2,500	2,500
	Ultimate elongation, minimum %	450	400	300
HEAT RESISTANCE				
	Change in durometer hardness, maximum points	+10	+10	+10
D573 70 hour at 158 F	Change in tensile strength, maximum %	-25	-25	-25
	Change in ultimate elongation, maximum %	-25	-25	-25
COMPRESSION SET				
D395 Method B	22 hours @ 158 F, maximum %	25	25	25
OZONE				
D1149	25 pphm ozone in air by volume, 20% strain 100 F ± 2 F 48 hours mounting procedure D518, Procedure A	No Cracks	No Cracks	No Cracks
ADHESION				
D429,B	Bond made during vulcanization, pounds per inch	40	40	40
LOW TEMPERATURE TEST				
D746 Procedure B	Brittleness at -40 F	No Failure	No Failure	No Failure

TABLE B

ASTM Standard		50 Duro	60 Duro	70 Duro
PHYSICAL PROPERTIES				
D2240	Hardness	50+5	60+5	70+5
D412	Tensile strength, minimum psi	2,500	2,500	2,500
	Ultimate elongation, minimum %	400	350	300
HEAT RESISTANCE				
	Change in durometer hardness, maximum points	+15	+15	+15
D573	Change in tensile strength,			
70 hour	maximum %	-15	-15	-15
at 212 F	Change in ultimate elongation, maximum %	-40	-40	-40
COMPRESSION SET				
D395 Method B	22 hours @ 212 F, maximum %	35	35	35
OZONE				
D1149	100 pphm ozone in air by volume, 20% strain 100 F + 2 F 100 hours mounting procedure D518, Procedure A	No Cracks	No Cracks	No Cracks
ADHESION				
D429,B	Bond made during vulcanization, pounds per inch	40	40	40
LOW TEMPERATURE TEST				
D746 Procedure B	Brittleness at -40 F	No Failure	No Failure	No Failure

(c)	Thickness of Individual Layers of Elastomer (Laminated Bearing Only)	±1/8"
(d)	Variation from a Plane Parallel to the Theoretical Surface (as determined by measurements at the edges of the bearings)	
	Top	1/8"
	Sides	1/4"
	Individual Non-Elastic Laminates	1/8"
(e)	Position of Exposed Connection Members	1/8"
(f)	Edge Cover of Embedded Laminates or Connection Members	-0, +1/8"
(g)	Size of Holes, Slots, or Inserts	±1/8"
(h)	Position of Holes, Slots, or Inserts	±1/8"

25.5 QUALITY ASSURANCE

25.5.1 Whenever practical, the mechanical properties of the finished bearing shall be verified by laboratory test.

25.5.2 The following values shall be met under laboratory testing conditions of full size bearings:

25.5.2.1 Compressive strain of any layer of an elastomeric bearing shall not exeed 7 percent at 800 psi average unit pressure, or at the design dead load plus live load pressure if so indicated on the plans.

25.5.2.2 The shear resistance of the bearing shall not exceed 30 psi for 50 durometer, 40 psi for 60 durometer, or 50 psi for 70 durometer, Table A compounds; nor 50 psi for 50 durometer, 75 psi for 60 durometer, or 110 psi for 70 durometer TABLE B compounds at 25 percent strain of the total effective rubber thickness after an extended four-day ambient temperature of -20 F.

SECTION 26 - CONSTRUCTION OF TUNNELS USING STEEL TUNNEL LINER PLATES

26.1 SCOPE

These specifications are intended to cover the installation of tunnel liner plates in tunnels constructed by conventional tunnel methods. For the purposes of these specifications, tunnels excavated by full face, heading and bench, or multiple drift procedures are considered conventional methods. Liner plates used with any construction procedure utilizing a full or partial shield, a tunneling machine, or other piece of equipment which will exert a force upon the liner plates for the purpose of propelling, steering, or stabilizing the equipment are considered special cases and are not covered by these specifications.

26.2 DESCRIPTION

26.2.1 This item shall consist of furnishing cold formed steel tunnel liner plates conforming to these specifications and of the sizes and dimensions required on the plans, and installing such plates at the locations designated on the plans by the Engineer, and in conformity with the lines and grades established by the Engineer. The completed liner shall consist of a series of steel liner plates assembled with staggered longitudinal joints. Liner plates shall be fabricated to fit the cross section of the tunnel. Liner plates herein described must meet the Sectional Properties of thickness, area, and moment of inertia, as listed in Division 1, Article 16.3.

26.2.2 All plates shall be connected by bolts on both longitudinal and circumferential seams or joints and shall be so fabricated as to permit complete erection from the inside of the tunnel.

26.2.3 Grout holes 2 inches or larger in diameter shall be provided as shown on the plans to permit grouting as the erection of tunnel liner plates progresses.

26.3 FORMING AND PUNCHING OF LINER PLATES

All plates shall be formed to provide circumferential flanged joints. Longitudinal joints may be flanged or of the offset lap seam type. All plates shall be punched for bolting on both longitudinal and circumferential seams or joints. Bolt spacing in circumferential flanges shall be in accordance with the manufacturer's standard spacing and shall be a multiple of the plate length so that plates having the same curvature shall be interchangeable and will permit staggering of the longitudinal seams. Bolt spacing at flanged longitudinal seams shall be in accordance with the manufacturer's standard spacing. For lapped longitudinal seams, bolt size and spacing shall be in accordance with the manufacturer's standard but not less than that required to meet the longitudinal seam strength requirements of Article 15.3.2.

26.4 INSTALLATION

26.4.1 All liner plates for the full length of a specified tunnel shall be of one type only, either the flanged or the lapped seam type of construction.

26.4.2 Liner plates shall be assembled in accordance with the manufacturer's instruction.

26.4.3 Coated plates shall be handled in such a manner as to prevent bruising, scaling, or breaking of the coating. Any plates that are damaged during handling or placing, shall be replaced by the Contractor at his expense, except that small areas with minor damage may be repaired by the Contractor as directed by the Engineer.

26.4.4 When and as designated by the Engineer, voids occuring between the liner plate and the tunnel wall shall be force-grouted. The grout shall be forced through the grouting holes in the plates with such pressure that all voids will be completely filled.

26.4.5 Full compensation for back packing or grouting shall be considered as included in the contract price paid for tunnel and no separate payment will be made therefor.

26.5 MEASUREMENT

The length of tunnel to be paid for will be the length measured on the tunnel liner plate invert.

26.6 PAYMENT

Payment for the length of each size of tunnel as determined under measurement shall be at the contract unit prices per linear foot bid for the various sizes, which payment shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals to complete this item, including removal and disposal of material resulting from the excavation of the bore and force-grouting voids.

SECTION 27 - TFE BEARING SURFACES

27.1 DESCRIPTION

Prefabricated fixed and expansion bearings having working surfaces of TFE conforming to the design requirements of Division 1, Section 15 shall conform with the following material, manufacturing, and test requirements.

27.2 MATERIALS

27.2.1 GENERAL

The virgin TFE resin, filled or unfilled TFE sheets, TFE fabric interlocked bronze and TFE structures, and TFE-Perforated metal composite, back-up materials and all other parts of the fixed or expansion bearings shall have the friction, mechanical, physical, and weathering properties prescribed in this Specification or shown on the plans.

27.2.2 TFE RESIN

TFE resin shall be virgin material (not reprocessed) meeting the requirements of ASTM designation D 1457. Specific Gravity shall be 2.13 - 2.19. Melting point shall be 623 F $\pm$2.

27.2.3 FILLER MATERIAL

Filler material, when used, shall be milled glass fibers, carbon or other approved inert filler materials.

27.2.4 ADHESIVE MATERIAL

Adhesive material shall be an epoxy resin meeting the requirements of Federal Specification MMM-A-134, FEP film or equal, as approved by the Engineer.

27.2.5 UNFILLED TFE SHEET

Finished unfilled TFE sheet shall be made from virgin TFE resin and shall conform to the following requirements:

Tensile Strength (minimum)	ASTM D 1457	2,800 psi
Elongation (minimum)	ASTM D 1457	200%

27.2.6 FILLED TFE SHEET

27.2.6.1 Filled TFE sheet shall be made from virgin TFE resin uniformly blended with inert filler material.

27.2.6.2 Finished filled TFE sheets containing glass fiber or carbon shall conform to the following requirements:

Mechanical	ASTM Method	15% Glass Fibers	25% Carbon
Tensile Strength (minimum)	D-1457	2,000 psi	1,300 psi
Elongation (minimum)	D-1457	150%	75%
Physical			
Specific Gravity (minimum)	D-792	2.20	2.10
Melting Point	D-1457	327 C $\pm$ 10 C	327 C $\pm$ 10C

27.2.7 FABRIC CONTAINING TFE FIBERS

The fabric will be manufactured from oriental multifilament TFE fluorocarbon fibers and other fibers as required by propietary designs. Typical physical properties of the TFE fibers should be as follows:

Tensile strength (minimum)	D-2256	24,000 psi
Elongation (minimum)	D-2256	75%

27.2.8 INTERLOCKED BRONZE AND FILLED TFE STRUCTURES

An interlocking bronze and filled TFE structure consisting of a phosphor bronze plate with an 0.010" thick porous bronze surface layer into which is impregnated a lead/TFE compound. There shall be an overlay of compounded TFE not less than 0.001" thick. The phosphor bronze back plate shall conform to ASTM B100 and the porous bronze layer shall conform to ASTM B103.

27.2.9 TFE METAL COMPOSITE

TFE metal composite shall consist of virgin TFE molded on each side and completely through a 1.32" perforated stainless steel ASTM A240, Type 304 sheet.

27.2.10 SURFACE TREATMENT

Where TFE sheets are to be epoxy bonded, one side of the TFE sheet shall be factory treated by an approved manufacturer by the sodium napthalene or sodium ammonia process.

27.2.11 STAINLESS STEEL MATING SURFACE

Stainless steel mating surfaces when used shall be 20 gage minimum thickness and conform to ASTM A240 type 304 with a surface finish less than 20 micro inches root mean square (rms). Stainless steel

mating surfaces shall be polished or rolled as necessary to meet the friction requirements of this Specification.

27.3 MANUFACTURING REQUIREMENTS

27.3.1 GENERAL

27.3.1.1 The expansion bearing shall be manufactured to the dimensions, and to meet the requirements of the method of fastening to the structure as shown in the plans.

27.3.1.2 TFE material shall be factory-bonded, mechanically connected, or recessed into the back-up material as shown on the plans.

27.3.2 TFE SHEETS

27.3.2.1 The bonding shall be performed at the factory of the manufacturer of the fixed or expansion bearings under controlled conditions and in accordance with the written instructions of the manufacturer of the approved adhesive system. After completion of the bonding operation the TFE surface shall be smooth and free from bubbles. Filled TFE surfaces shall then be polished.

27.3.2.2 When mechanically fastened, TFE sheet shall be fastened as shown in the plans with the size, type, and number of fasteners required taking care to have full bearing of the fastener used in the TFE sheet and back-up material.

27.3.2.3 FABRIC CONTAINING TFE FIBERS

The fabric shall be bonded or mechanically attached to a rigid substrate. The fabric shall be capable of carrying unit loads of 10,000 psi without cold flow. The fabric-substrate bond shall be capable of withstanding a shear force equal to 10 percent of the perpendicular or normal application loading without delamination in addition to the shear force developed as a result of the natural bearing friction shear force.

27.4 TESTING AND ACCEPTANCE

27.4.1 GENERAL

At the discretion of the Engineer, the manufacturer may be required to furnish facilities for the test and inspection of the completed bearings or representative samples in his plant or at an independent test facility. Inspectors, if appointed, shall be allowed free access to the necessary parts of the manufacturers plant and test facility.

27.4.2 TEST SPECIMENS

If required by the Engineer and available test facilities permit, it is preferable that complete bearings be tested. 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 100 kips 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. Manufacturers certification of the steel, elastomeric pads, preformed fabric pads, TFE, and other materials used in the construction of the bearings shall be furnished along with notification of fabrication completion.

27.4.3 TEST METHOD

27.4.3.1 The test method and equipment shall be approved by the Engineer and include the following requirements:

(a) The test must be arranged so that the coefficient of friction on the first movement of the manufactured bearing can be determined.

(b) The bearing surface shall be cleaned prior to testing.

(c) The test shall be conducted at maximum working stress for the TFE surface with the test load applied continuously for 12 hours prior to measuring friction.

(d) The first movement static and dynamic coefficient of friction of the test bearing shall be determined at a sliding speed of less than 1 inch per minute and shall not exceed the coefficient of friction for design in Article 15.2 - Division I.

(e) The bearing specimen shall then be subjected to 100 movements of at least 1 inch of relative movement and if the test facility permits, the full design movement at a speed of less than 1 foot per minute. Following this test the static and kinetic coefficient of friction shall be determined again and shall not exceed the values measured in (d) above. The bearing or specimen shall show no appreciable sign of bond failure or other defects.

27.4.3.2 Bearings represented by test specimens passing the above requirements will be approved for use in the structure subject to on-site inspection for visible defects.

27.5 PACKAGING AND IDENTIFICATION MARKING

Packaging shall be accomplished in such a manner to ensure that the bearings during shipment and storage will be protected against damage from handling, weather, or any normal hazard. Each completed bearing shall have its components clearly identified, be securely taped or otherwise fastened for shipment, and marked on its top as to location in each structure in the project in conformity with the plans.

SECTION 28 - CONSTRUCTION AND INSTALLATION OF SOIL-REINFORCED CONCRETE STRUCTURE INTERACTION SYSTEMS

28.1 GENERAL

28.1.1 This item shall consist of furnishing and placing precast soil-reinforced concrete structure interaction systems conforming to these specifications and of the sizes, strengths, and dimensions required on the plans, and installing such structures at the places designated on the plans or by the Engineer, and in conformity with the lines and grades established by the Engineer. Precast reinforced concrete pipe shall be either circular, arch, or elliptical, as specified or shown on the plans. Precast reinforced concrete box shall be of the dimensions as specified or shown on the plans.

28.1.2 Design requirements shall be in accordance with Section 17 - Division I.

28.2 PIPE MATERIALS

Material requirements shall be as required by AASHTO M 170 or M 242 (ASTM 676 or C 655) for precast reinforced concrete circular pipe, AASHTO M 206 (ASTM C 506) for precast reinforced concrete arch pipe, AASHTO M 207 (ASTM C 507) for precast reinforced concrete elliptical pipe, and AASHTO M 259 and M 273 (ASTM C 789 and C 850) for precast reinforced concrete box sections.

28.3 JOINTS

28.3.1 Joints for reinforced concrete pipe and precast reinforced concrete box sections shall comply with the property requirements set forth in the specifications. All joints, including any connection, shall be capable of transferring the required shear across the joint.

28.3.2 The Contractor shall furnish to the Engineer a certificate of compliance that the material being furnished conforms to the joint property requirements. Field tests may be required by the Engineer whenever there is a question regarding compliance with the requirements.

28.4 CULVERT FOUNDATION

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 suitable material. 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 suitable material. Where an unsuitable material (peat, muck, etc.) 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.

28.5 BEDDING

When, in the opinion of the Engineer, the in situ soil does not provide a suitable bedding, a bedding conforming to Figures 28.5A and 28.5B shall be provided for the type of installation specified.

28.6 FILL REQUIREMENTS

28.6.1 TRENCH CONDITION

Backfill material shall be installed to the limits shown on Figure 28.5A. The trench shall have vertical walls. Over-excavating and sloping sidewalls shall not be permitted.

28.6.2 EMBANKMENT CONDITION

Sidefill material shall be installed to the limits shown on Figure 28.5B.

28.6.3 FILL MATERIAL

Fill material shall be placed in layers with a maximum thickness of 1 foot 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 brought up evenly and simultaneously on both sides of the culvert. 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.

28.7 MULTIPLE INSTALLATIONS

Pipe and box sections used in parallel installations shall have positive lateral bearing between the sides of adjacent pipe or box sections. Compacted earthfill, granular backfill, or grouting between the units are considered means of providing such positive bearing.

28.8 COVER OVER CULVERT DURING CONSTRUCTION

Culverts shall be protected by a minimum of 2 feet to prevent damage before permitting heavy construction equipment to pass over them during construction.

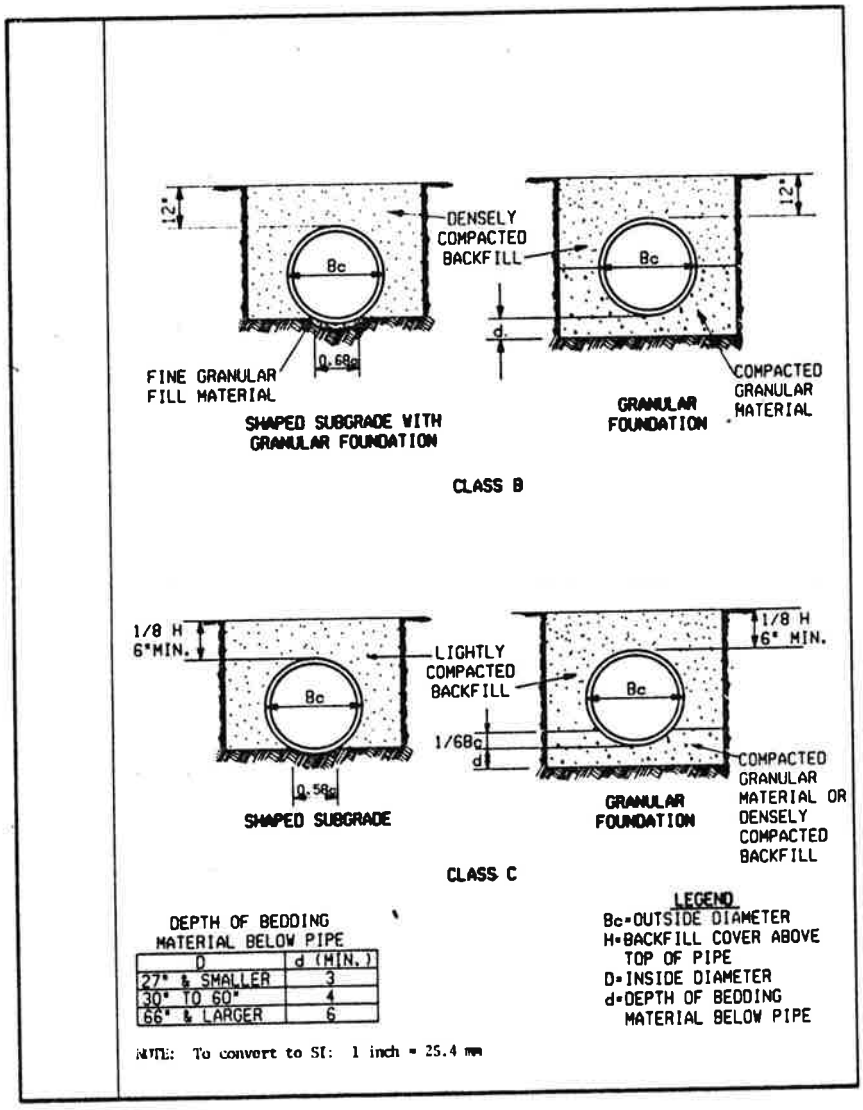
28.9 WORKMANSHIP AND INSPECTION

28.9.1 WORKMANSHIP

In addition to compliance with the details of construction, the completed structure shall show careful finished workmanship in all particulars.

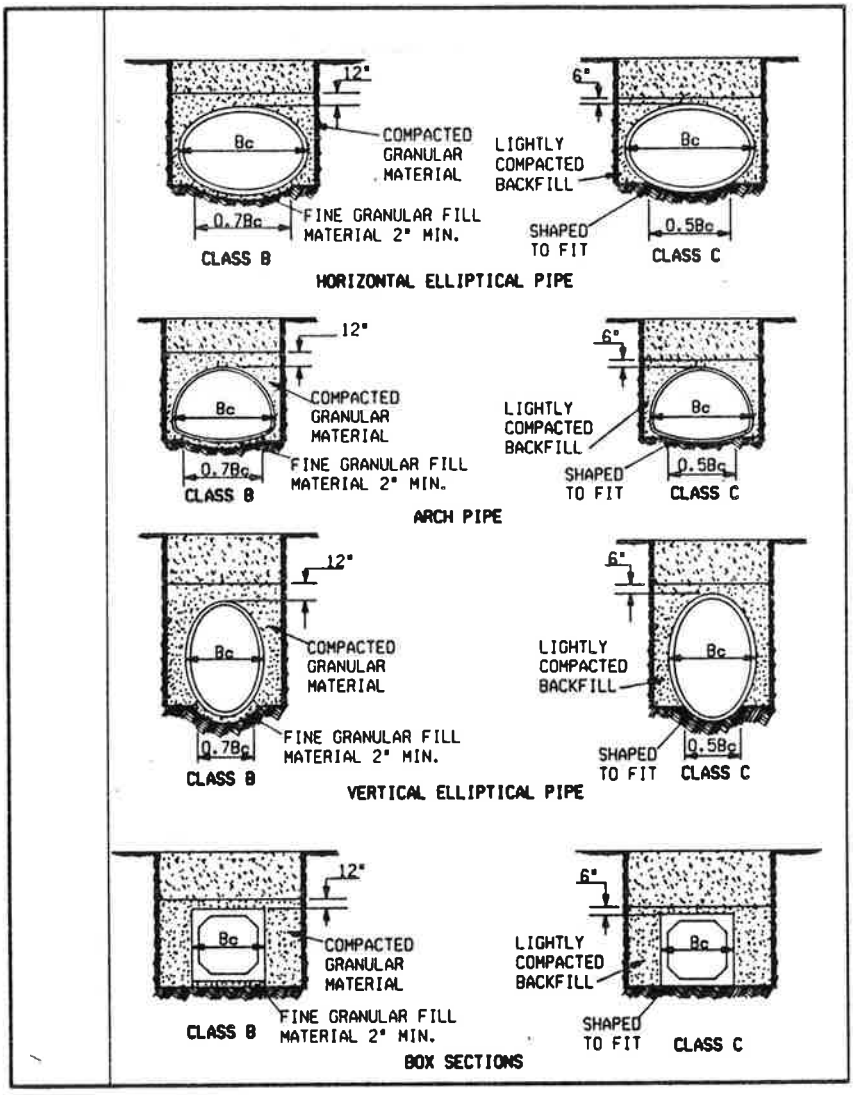
28.9.2 CRACKS

Cracks in an installed precast concrete culvert that exceed 0.01" width shall be appraised considering the structural integrity and the service life of the culvert.



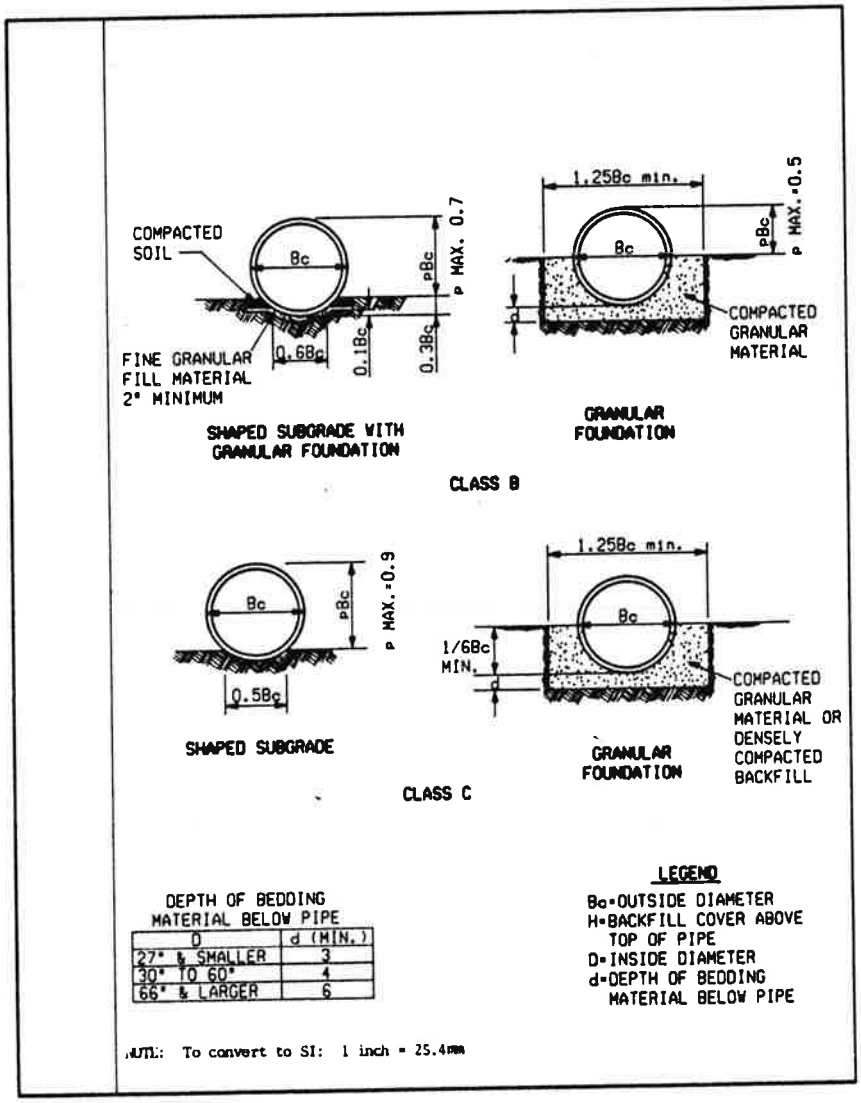
Trench Beddings Circular Pipe

Figure 28.5A



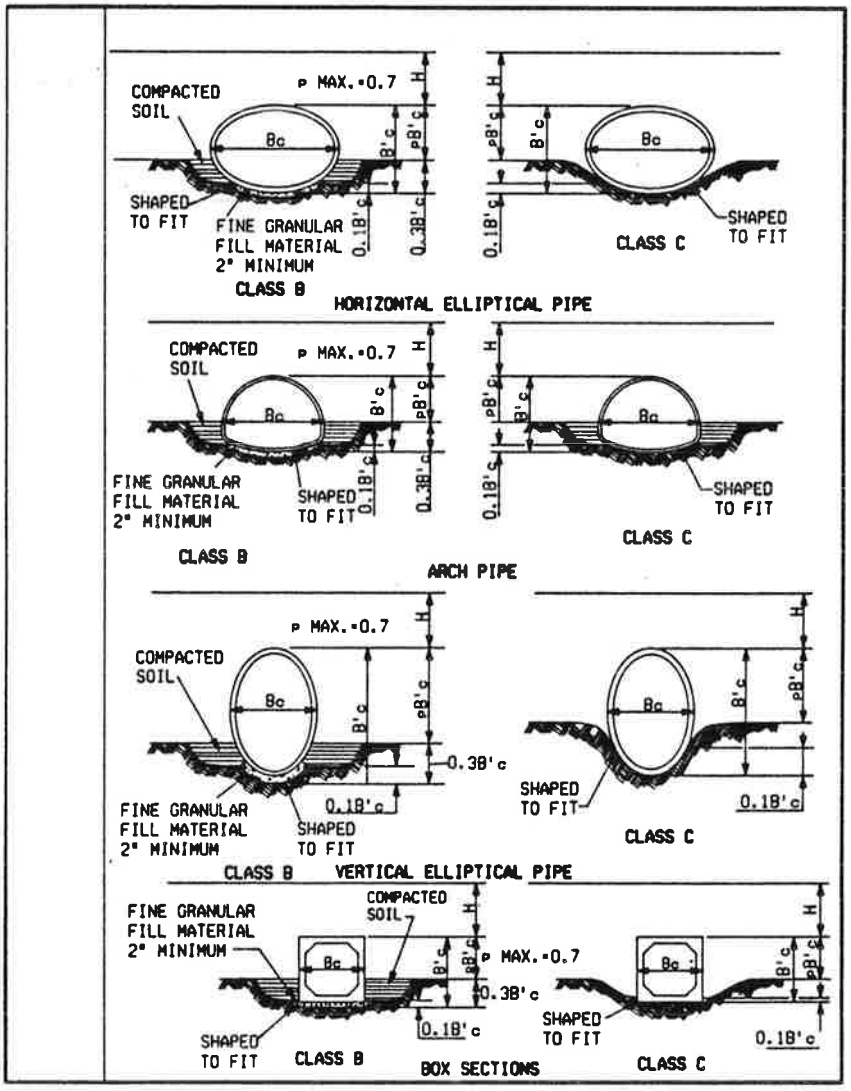
Trench Beddings (continued)

Figure 28.5A



Embankment Beddings Circular Pipe

Figure 28.5B



Embankment Beddings (continued)

Figure 28.5B

28.9.2.1 NON-CORROSIVE ENVIRONMENT

All cracks over 0.10" width shall be sealed by an approved method. Cracks 0.10" or less in width are acceptable without repair.

28.9.2.2 CORROSIVE ENVIRONMENT

All cracks over 0.01" shall be sealed by an approved method. Cracks 0.01" or less in width are acceptable without repair.

28.10 METHOD OF MEASUREMENT

Culverts shall be measured in linear feet installed in place, completed, and accepted. The number of linear feet shall be the average of the top and bottom centerline lengths for pipe and box sections.

28.11 BASIS OF PAYMENT

The length determined as herein given shall be paid for at the contract unit prices per linear foot 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, but shall not constitute payment for concrete or masonry headwalls and foundations, or for excavations.