American Association of
State Highway and
Transportation Officials

Jack Lettiere, Jr., President
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ERRATA

Dear Customer:

Due to errors found after the publication had been completed, AASHTO has reprinted the pages listed below and made the following errata changes to the *AASHTO LRFD Bridge Construction Specifications*, 2nd Edition:

Replacement Pages	Affected Article	Errata Change
p. 3-5/p. 3-6	3.2.3.1, C3.2.3.1	Add "PS 1" to standard description and provide title.
p. 4-15/4-16	4.4.6	Remove extraneous bullet points from commentary column. (This is an editorial correction to clarify that there is no commentary for this article.)
p. 4-19/p. 4-20	References	Add missing entries to reference list for Section 4.
p. 6-11/p. 6-12	6.5.5.3	Display last row of Table 6.5.5.3-1.
p. 7-3/p. 7-4	7.3.6.2	Correct SI sieve sizes.
	7.3.6.3	Correct SI sieve size.
p. 7-15/p. 7-16	References	Add missing entry to reference list for Section 7.
p. 8-9/p. 8-10	C8.5.3	Correct SI volume.
p. 8-23/p. 8-24	8.8.3	Correct SI volume.
p. 8-43/p. 8-44	C8.13.7.1.4	Correct SI dimensions.
p. 8-65/p. 8-66	References	Add missing entry to reference list for Section 8.
p. 10-33/p. 10-34	References	Add missing entries to reference list for Section 10.
p. 11-5/p. 11-6	11.3.2.1	Correct typographical error in article citation in last paragraph.
p. 11-55/p. 11-56	References	Add missing entries to reference list for Section 11.
p. 13-11/p. 13-12	References	Add missing entry to reference list for Section 13.
p. 16-15/p. 16-16	References	Add missing entries to reference list for Section 16.
p. 17-1/p. 17-2	C17.3.2	Delete extraneous commentary.

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Replacement Pages	Affected Article	Errata Change
p. 18-39/p. 18-40	References	Add missing entry to reference list for Section 18.
p. 26-11/p. 26-12	26.5.4.1	Display entire Figure 26.5.4.1-1.
p. 27-5/p. 27-6	27.5.2.2	Display entire Figure 27.5.2.2-3.
p. 27-11/p. 27-12	27.5.3	Display entire Figure 27.5.3-1.
p. 27-17/p. 27-18	References	Add missing entry to reference list for Section 27.
p. 29-1/p. 29-2	29.2	Update citation in paragraph 4.
p. 29-3/p. 29-4	References	Update entry to reference list for Section 29.
p. 30-3/p. 30-4	30.5.4	Correct SI dimension in second paragraph.
p. 31-7/p. 31-8	31.4.1	Display entire right column of Table 31.4.1-1.
p. 31-11/p. 31-12	31.4.11.2	Correct symbols in Eq. 31.4.11.2-1.
	31.4.11.3	Correct symbols in Eq. 31.4.11.3-1.
	31.4.11.4	Correct symbols in Eq. 31.4.11.4-1.
p. 31-15/p. 31-16	31.5.5	Remove extraneous article number from commentary column. (This is an editorial correction to clarify that there is no commentary for this article.)
p. 31-19/p. 31-20	References	Add missing entries to reference list for Section 31.
p. 32-9/p. 32-10	References	Add missing entry to reference list for Section 32.
p. A-1/p. A-2	Appendix/4.4.4.2	Correct Eqs. 4.4.4.2-1 and 4.4.4.2-2.
p. A-9/p. A-10	Appendix/16.2.6.1	Correct second to last row of Table 16.2.6.1-1a.
p. A-21/p. A-22	Appendix	Correct symbols in SI version of Eq. 31.4.11.2-1.

Please substitute the original pages of text with the enclosed pages. We apologize for any inconvenience this may have caused.

AASHTO Publications Staff

3.2.3 Formwork Design and Construction

3.2.3.1 General

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

Forms for concrete surfaces exposed to view shall produce a smooth surface of uniform texture and color substantially equal to that which would be obtained with the use of plywood conforming to the National Institute of Standards and Technology Product Standard PS 1 for Exterior B-B Class I Plywood. Panels lining such forms shall be arranged so that the joint lines form a symmetrical pattern conforming to the general lines of the structure. The same type of form-lining material shall be used throughout each element of a structure. Such forms shall be sufficiently rigid so that the undulation of the concrete surface shall not exceed 0.125 in. (3 mm) when checked with a 5.0-ft (1500-mm) straightedge or template. All sharp corners shall be filleted with approximately 0.75-in. (20-mm) chamfer strips.

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

C3.2.3.1

Forms for concrete structures using plywood refers to the National Institute of Standards and Technology Product Standards PS 1, *Construction and Industrial Plywood*.

3.2.3.2 Design

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

C3.2.3.2

Formwork design refers to ACI 347-78, *Recommended Practice for Concrete Formwork.*

3.2.3.3 Construction

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

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

Except as provided herein, metal ties or anchorages within the forms shall be so constructed as to permit their removal to a depth of at least 1.0 in. (25 mm) from the face without injury to the concrete. Ordinary wire ties may be used only when the concrete will not be exposed to view and where the concrete will not come in contact with salts or sulfates. Such wire ties, upon removal of the forms, shall be cut back at least 0.25 in. (6 mm) from the face of the concrete with chisels or nippers; for green concrete, nippers shall be used. Fittings for metal ties shall be of such design that, upon their removal, the cavities that 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.

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

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

3.2.3.4 Tube Forms

Tubes used as forms to produce voids in concrete slabs shall be properly designed and fabricated or otherwise treated to make the outside surface waterproof. Prior to concrete placement, such tubes shall be protected from the weather and stored and installed by methods that prevent distortion or damage. The ends of tube forms shall be covered with caps that shall be made mortar tight and waterproof. If wood or other material that expands when moist is used for capping tubes, a premolded rubber joint filler 0.25 in. (6 mm) in thickness shall be used around the perimeter of the caps to permit expansion. A polyvinyl chloride (PVC) vent tube shall be provided near each end of each tube. These vents shall be constructed to provide positive venting of the voids. After exterior form removal, the vent tube shall be trimmed to within 0.5 in. (15 mm) of the bottom surface of the finished concrete.

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

3.2.3.5 Stay-in-Place Forms

Stay-in-place deck soffit forms, such as corrugated metal or precast concrete panels, may be used if shown in the contract documents or approved by the Engineer. Prior to the use of such forms, the Contractor shall provide a complete set of details to the Engineer for review and approval. Unless otherwise noted, the contract documents for structures should be dimensioned for the use of removable forms. Any changes necessary to accommodate stay-in-place forms, if approved, shall be at the expense of the Contractor.

where:

S_f = settlement at failure, in.

D = pile diameter or width, in.

S = elastic deformation of total unsupported pile length, in.

The top elevation of the test pile shall be determined immediately after driving and again just before load testing to check for heave. Any pile that heaves more than 0.25 in. (6 mm) shall be redriven or jacked to the original elevation prior to testing. Unless otherwise specified in the contract documents, a minimum three-day waiting period shall be observed between the driving of any anchor piles or the load test pile and the commencement of the load test.

4.4.5 Splicing of Piles

4.4.5.1 Steel Piles

Full-length piles shall be used where practicable. If splicing is permitted, the method of splicing shall be as specified in the contract documents or as approved by the Engineer. The arc method of welding shall be preferred when splicing steel piles. Welding shall only be performed by certified welders.

4.4.5.2 Concrete Piles

Concrete piles shall not be spliced, other than to produce short extensions as permitted herein, unless specified in the contract documents or in writing by the Engineer.

Short extensions or “build-ups” may be added to the tops of reinforced concrete piles to correct for unanticipated events. After the driving is completed, the concrete at the end of the pile shall be cut away, leaving the reinforcing 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 not less than the quality used in the pile. Just prior to placing concrete, the top of the pile shall be thoroughly flushed with water, allowed to dry, then covered with a thin coating of neat cement, 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.

4.4.5.3 Timber Piles

Timber piles shall not be spliced unless specified in the contract documents or in writing by the Engineer.

4.4.6 Defective Piles

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 excessive 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, by improper driving, driven out of its proper location, or driven below the butt elevation fixed by the contract documents 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:

- The pile shall be withdrawn and replaced by a new and, if necessary, longer pile.
- A second pile shall be driven adjacent to the defective or low pile.
- 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.

All piles pushed up by the driving of adjacent piles or by any other cause shall be driven down again.

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

4.4.7 Pile Cut-Off

4.4.7.1 General

All piles shall be cut off to a true plane at the elevations required and anchored to the structure, as shown in the contract documents.

All cut-off lengths of piling shall remain the property of the Contractor and shall be properly disposed of.

4.4.7.2 Timber Piles

Timber piles which support timber caps or grillage shall be sawn to conform to the plane of the bottom of the superimposed structure. 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 added or otherwise freed from all broomed, splintered, or otherwise injured material.

C4.4.7.2

Payment under the appropriate pay items for pile splices, shoes, and lugs includes full compensation for all costs involved with furnishing all materials and performing the work involved with attaching or installing splices, shoes, or lugs to the piles.

REFERENCES

AASHTO. 2002. *Standard Specifications for Highway Bridges*, 17th Edition, HB-17, American Association of State Highway and Transportation Officials, Washington, DC.

AASHTO. 2004. *AASHTO LRFD Bridge Design Specifications*, 3rd Edition, LRFDUS-3 or LRFDSI-3, American Association of State and Highway Transportation Officials, Washington, DC. Available in customary U.S. units or SI units.

AASHTO. 2004. *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 24th Edition, HM-24, American Association of State Highway and Transportation Officials, Washington, DC.

AWPA. 2002. *Standard for the Care of Preservative-Treated Wood Products*, AWPA M4-02, American Wood-Preservers' Association, Selma, AL.

Engineering News-Record formula. Based on a formula published in 1888 by A. M. Wellington, editor of *Engineering News-Record*, New York, NY.

where:

AL = Alignment load

DL = Design load for ground anchor

* = Graph required, as specified herein

The maximum test load in a performance test shall be held for 10 min. The jack shall be repumped as necessary in order to maintain a constant load. The loadhold period shall start as soon as the maximum test load is applied, and the ground anchor movement shall be measured and recorded at 1 min, 2, 3, 4, 5, 6, and 10 min. If the ground anchor movements between 1 min and 10 min exceeds 0.04 in. (1.0 mm), the maximum test load shall be held for an additional 50 min. If the load-hold is extended, the ground anchor movement shall be recorded at 15 min, 20, 25, 30, 45, and 60 min.

A graph shall be constructed showing a plot of ground anchor movement versus load for each load increment marked with an asterisk (*) in Table 6.5.5.2-1 and a plot of the residual ground anchor movement of the tendon at each alignment load versus the highest previously applied load. Graph format shall be approved by the Engineer prior to use.

The alignment load is a small load, normally less than ten percent of the design load, applied to the ground anchor in order to keep the testing equipment in position during testing.

6.5.5.3 Proof Test

Those anchors not subjected to a performance test shall be tested as specified herein.

The proof test shall be performed by incrementally loading the ground anchor in accordance with the following schedule unless a different maximum test load and schedule are indicated in the contract documents. The load shall be raised from one increment to another immediately after recording the ground anchor movement. The ground anchor movement shall be measured and recorded to the nearest 0.001 in. (0.025 mm) with respect to an independent fixed reference point at the alignment load and at each increment of load. The load shall be monitored with a pressure gage. At load increments other than the maximum test load, the load shall be held just long enough to obtain the movement reading.

Table 6.5.5.3-1 Proof Test Schedule.

Load	Load
AL	1.00*DL*
0.25*DL*	1.20*DL*
0.50*DL*	1.33*DL* (max. test load)
0.75*DL*	Reduce to lock-off load

C6.5.5.3

If a different maximum test load is to be required, a schedule similar to the one given in this article should be described in the contract documents.

where:

AL = Alignment load

DL = Design load for ground anchor

The maximum test load in a proof test shall be held for 10 min. The jack shall be repumped as necessary in order to maintain a constant load. The load-hold period shall start as soon as the maximum test load is applied, and the ground anchor movement shall be measured and recorded at 1 min, 2, 3, 4, 5, 6, and 10 min. If the ground anchor movement between 1 min and 10 min exceeds 0.04 in. (1.0 mm), the maximum test load shall be held for an additional 50 min. If the load-hold is extended, the ground anchor movement shall be recorded at 15 min, 20, 30, 45, and 60 min. A graph shall be constructed showing a plot of ground anchor movement versus load for each load increment in the proof test. Graph format shall be approved by the Engineer prior to use.

6.5.5.4 Creep Test

Creep tests shall be performed if specified in the contract documents. The Engineer shall select the ground anchors to be creep tested.

The creep test shall be made by incrementally loading and unloading the ground anchor in accordance with the performance test schedule used. At the end of each loading cycle, the load shall be held constant for the observation period indicated in the creep test schedule below unless a different maximum test load is indicated in the contract documents. The times for reading and recording the ground anchor movement during each observation period shall be 1 min, 2, 3, 4, 5, 6, 10, 15, 20, 25, 30, 45, 60, 75, 90, 100, 120, 150, 180, 210, 240, 270, and 300 min as appropriate. Each load-hold period shall start as soon as the test load is applied. In a creep test, the pressure gage and reference pressure gage shall be used to measure the applied load, and the load cell shall be used to monitor small changes of load during a constant load-hold period. The jack shall be repumped as necessary in order to maintain a constant load.

Table 6.5.5.4-1 Creep Test Schedule.

AL	Observation Period, min
0.25*DL*	10
0.50*DL*	30
0.75*DL*	30
1.00*DL*	45
1.20*DL*	60
1.33*DL*	300

C6.5.5.4

If creep tests are required, at least two ground anchors should be creep-tested. If a different maximum test load is to be required, a schedule similar to this one should be described in the contract documents.

7.3.2 Reinforcing Steel

Reinforcing steel shall conform to the requirements of Section 9, "Reinforcing Steel."

7.3.3 Structural Steel

Structural steel shall conform to AASHTO M 270M/M 270 (ASTM A 709/A 709M), Grade 36 (Grade 250), unless otherwise specified in the contract documents.

7.3.4 Timber

Timber shall conform to the requirements of Section 16, "Timber Structures," and Article 4.2.2, "Timber Piles."

7.3.5 Drainage Elements

7.3.5.1 Pipe and Perforated Pipe

Pipe and perforated pipe shall conform to Subsection 708, "Concrete, Clay, and Plastic Pipe," and Section 709, "Metal Pipe," of the *AASHTO Guide Specifications for Highway Construction*.

7.3.5.2 Filter Fabric

Filter fabric shall conform to Subsection 620, "Filter Fabric," of the *AASHTO Guide Specifications for Highway Construction*,

7.3.5.3 Permeable Material

Permeable material shall conform to Subsection 704, "Aggregate for Drainage," of the *AASHTO Guide Specifications for Highway Construction*, unless otherwise specified in the contract documents or on the approved working drawings.

7.3.5.4 Geocomposite Drainage Systems

Geocomposite drainage systems shall conform to the requirements specified in the contract documents or the approved working drawings.

7.3.6 Structure Backfill Material

7.3.6.1 General

All structure backfill material shall consist of material free from organic material or other unsuitable material as determined by the Engineer. Gradation will be determined by AASHTO T 27 (ASTM C 136). Grading shall be as follows, unless otherwise specified.

Sieve Size	*Percent Passing*
3.0 in. (75 mm)	100
No. 4 (4.75 mm)	35–100
No. 30 (600 µm)	20–100
No. 200 (75 µm)	0–15

7.3.6.2 Crib and Cellular Walls

Structure backfill material for crib and cellular walls shall be of such character that it will not sift or flow through openings in the wall. For wall heights over 20.0 ft (6000 mm), the following grading shall be required:

Sieve Size	*Percent Passing*
3.0 in. (75 mm)	100
No. 4 (4.75 mm)	25–70
No. 30 (600 µm)	5–20
No. 200 (75 µm)	0–5

7.3.6.3 Mechanically Stabilized Earth Walls

Structure backfill material for mechanically stabilized earth walls shall conform to the following grading, internal friction angle and soundness requirements:

Sieve Size	*Percent Passing*
4.0 in. (100 mm)	100
No. 40 (425 µm)	0–60
No. 200 (75 µm)	0–15

*Plasticity Index (PI), as determined by AASHTO T 90, shall not exceed 6.

The material shall exhibit an angle of internal friction of not less than 34 degrees, as determined by the standard Direct Shear Test, AASHTO T 236 (ASTM D 3080), on the portion finer than the No. 10 (2.00-mm) sieve, utilizing a sample of the material compacted to 95 percent of AASHTO T 99, Methods C or D (with oversized correction as outlined in Note 7) at optimum moisture content. No testing is required for backfills where 80 percent of sizes are greater than 0.75 in. (19 mm).

The materials shall be substantially free of shale or other soft, poor durability particles. The material shall have a magnesium sulfate soundness loss of less than 30 percent after four cycles.

Additionally, the backfill material shall meet the following electrochemical requirements when steel soil reinforcement is to be used:

constructing the earth-retaining systems including, but not limited to, earthwork, piles, footings, and drainage systems, complete in place, as specified in the contract documents, in these Specifications and as directed by the Engineer.

Full compensation for revisions to drainage system or other facilities made necessary by the use of an alternative earth-retaining system shall be considered as included in the contract price paid per square foot (square meter) for earth-retaining system and no adjustment in compensation will be made therefore.

REFERENCES

AASHTO. 1998. *AASHTO Guide Specifications for Highway Construction*, GSH-8, American Association of State Highway and Transportation Officials, Washington, DC.

AASHTO. 2004. *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 24th Edition, HM-24, American Association of State Highway and Transportation Officials, Washington, DC.

GSA. 1966. *Adhesive, Bonding Vulcanized Rubber to Steel*, Federal Specification MMM-A-121, U.S. General Services Administration.

- up to 50 percent of the required portland cement with slag conforming to AASHTO M 302 (ASTM C 989), or

- up to ten percent of the required portland cement with silica fume conforming to AASHTO M 307 (ASTM C 1240).

When any combination of fly ash, slag, and silica fume are used, the Contractor will be permitted to replace up to 50 percent of the required portland cement. However, no more than 25 percent shall be fly ash and no more than ten percent shall be silica fume. The weight (mass) of the mineral admixture used shall be equal to or greater than the weight (mass) of the portland cement replaced. In calculating the water-cementitious materials ratio of the mix, the weight (mass) of the cementitious materials shall be considered to be the sum of the weight (mass) of the portland cement and the mineral admixtures.

For Class P(HPC) and Class A(HPC) concrete, mineral admixtures (pozzolans or slag) shall be permitted to be used as cementitious materials with portland cement in blended cements or as a separate addition at the mixer. The amount of mineral admixture shall be determined by trial batches. The water-cementitious materials ratio shall be the ratio of the weight (mass) of water to the total cementitious materials, including the mineral admixtures. The properties of the freshly mixed and hardened concrete shall comply with specified values.

8.4.5 Air-Entraining and Chemical Admixtures

Air-entraining and chemical admixtures shall be used as specified in the contract documents. Otherwise, such admixtures may be used, at the option and expense of the Contractor when permitted by the Engineer, to increase the workability or alter the time of set of the concrete.

8.5 MANUFACTURE OF CONCRETE

The production of ready-mixed concrete and concrete produced by stationary mixers shall conform to the requirements of AASHTO M 157 and the requirements of this Article.

8.5.1 Storage of Aggregates

The handling and storage of concrete aggregates shall be such as to prevent segregation or contamination with foreign materials. The methods used shall provide for adequate drainage so that the moisture content of the aggregates is uniform at the time of batching. Different sizes of aggregate shall be stored in separate stock piles sufficiently removed from each other to prevent the material at the edges of the piles from becoming intermixed.

When specified in Table 8.2.2-1 or in the contract documents, the coarse aggregate shall be separated into two or more sizes in order to secure greater uniformity of the concrete mixture.

8.5.2 Storage of Cement

The Contractor shall provide suitable means for storing and protecting cement against dampness. Cement which for any reason has become partially set or which contains lumps of caked cement shall be rejected. Cement held in storage for a period of over three months if bagged or six months if bulk, or cement which for any reason the Engineer may suspect is damaged, shall be subject to a retest before being used in the work.

Copies of cement records shall be furnished to the Engineer showing, in such detail as the Engineer may reasonably require, the quantity used during the day or run at each part of the work.

8.5.3 Measurement of Materials

Materials shall be measured by weighing, except as otherwise specified in the contract documents 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 need not be weighed but bulk cement shall be weighed. The mixing water shall be measured by volume or by weight (mass). 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 and shall be tested, at the Contractor's expense, when deemed necessary by the Engineer.

When volumetric measurements are authorized for projects, the weight (mass) proportions shall be converted to equivalent volumetric proportions. In such cases, suitable allowance shall be made for variations in the moisture condition of the aggregates, including the bulking effect in the fine aggregate.

When sacked cement is used, the quantities of aggregates for each batch shall be exactly sufficient for one or more full sacks of cement and no batch requiring fractional sacks of cement will be permitted.

C8.5.3

The conventional sack of cement has a volume of 1.0 ft^3 and a weight of 94.0 lb (0.028 m^3 and a mass of 43 kg).

8.5.4 Batching and Mixing Concrete

8.5.4.1 Batching

The size of the batch shall not exceed the capacity of the mixer as guaranteed by the Manufacturer or as determined by the Standard Requirements of the Associated General Contractors of America.

the entire top surface of the work and so as to permit rapid lowering when necessary to retard or stop the flow of concrete. The discharge end shall be sealed closed at the start of work so as to prevent water from entering the tube before the tube is filled with concrete. After placement has started, the tremie tube shall be kept full of concrete to the bottom of the hopper. If water enters the tube after placement is started, the tremie shall be withdrawn, the discharge end resealed, and the placement restarted. When a batch is dumped into the hopper, the flow of concrete shall be induced by slightly raising the discharge end, always keeping it in the deposited concrete. The flow shall be continuous until the work is completed. When cofferdam struts prevent lateral movement of tremies, one tremie shall be used in each bay.

Concrete pumps used to place concrete under water shall include a device at the end of the discharge tube to seal out water while the tube is first being filled with concrete. Once the flow of concrete is started, the end of the discharge tube shall be kept full of concrete and below the surface of the deposited concrete until placement is completed.

8.7.5.3 Clean-Up

Dewatering may proceed after test specimens cured under similar conditions indicate that the concrete has sufficient strength to resist the expected loads. All laitance or other unsatisfactory materials shall be removed from the exposed surface by scraping, chipping, or other means which will not injure the surface of the concrete before placing foundation concrete.

8.8 CONSTRUCTION JOINTS

8.8.1 General

Construction joints shall be made only where specified in the contract documents, or shown in the pouring schedule, unless otherwise approved. All planned reinforcing steel shall extend uninterrupted through joints. In the case of emergency, construction joints shall be placed as directed by the Engineer and, if directed, additional reinforcing steel dowels shall be placed across the joint. Such additional steel shall be furnished and placed at the Contractor's expense.

8.8.2 Bonding

Unless otherwise specified in the contract documents, horizontal joints may be made without keys, and vertical joints shall be constructed with shear keys. Surfaces of fresh concrete at horizontal construction joints shall be rough floated sufficiently to thoroughly consolidate the surface and intentionally left in a roughened condition. Shear keys shall consist of formed depressions in the surface covering approximately one-third of the contact surface. The forms for keys shall be beveled so that removal will not damage the concrete.

All construction joints shall be cleaned of surface laitance, curing compound, and other foreign materials before fresh concrete is placed against the surface of the joint. Abrasive blast or other approved methods shall be used to clean horizontal construction joints to the extent that clean aggregate is exposed. All construction joints shall be flushed with water and allowed to dry to a surface dry condition immediately prior to placing concrete.

8.8.3 Bonding and Doweling to Existing Structures

When the contract documents specify that new concrete be bonded to existing concrete structures, the existing concrete shall be cleaned and flushed as specified in Article 8.8.2, "Bonding." When the contract documents show reinforcing dowels grouted into holes drilled in the existing concrete at such construction joints, the holes shall be drilled by methods that will not shatter or damage the concrete adjacent to the holes. The diameters of the drilled holes shall be 0.25 in. (6 mm) larger than the nominal diameter of the dowels unless shown otherwise in the contract documents. The grout shall be a neat cement paste of portland cement and water. The water content shall be not more than 4 gal/94 lb (15 L/43 kg) of cement. Retempering of grout will not be permitted. Immediately prior to placing the dowels, the holes shall be cleaned of dust and other deleterious materials, shall be thoroughly saturated with water, shall have all free water removed, and the holes shall be dried to a saturated surface-dry condition. Sufficient grout shall be placed in the holes so that no voids remain after the dowels are inserted. Grout shall be cured for a period of at least three days or until dowels are encased in concrete.

When specified in the contract documents or approved by the Engineer, epoxy may be used in lieu of portland cement grout for the bonding of dowels in existing concrete. When used, epoxy shall be mixed and placed in accordance with the Manufacturer's recommendations.

8.8.4 Forms at Construction Joints

When forms at construction joints overlap previously placed concrete, they shall be retightened before depositing new concrete. The face edges of all joints that are exposed to view shall be neatly formed with straight bulkheads or grade strips, or otherwise carefully finished true to line and elevation.

8.9 EXPANSION AND CONTRACTION JOINTS

8.9.1 General

Expansion and contraction joints shall be constructed at the locations and in accordance with the specified application temperature with the adhesive coated surface or surfaces exposed and uncovered before joining together. The assembled prisms are then curved and tested as instructed in Test 4.

The epoxy-bonding agent shall be deemed acceptable for the specified application temperature only when essentially total fracturing of concrete paste and aggregate occurs with no evidence of adhesive failure.

Construction situations may sometimes require application of the epoxy-bonding agent to the precast section prior to erecting, positioning, and assembling. This operation may require epoxy-bonding agents having prolonged open time. In general, where the erection conditions are such that the sections to be bonded are prepositioned prior to epoxy application, the epoxy-bonding agent shall have a minimum open time of 60 min within the temperature range specified for its application.

8.13.7.1.4 Test 4—Three-Point Tensile Bending Test

Testing Method: AASHTO T 126 (ASTM C 192) 6.0 × 6.0 × 9.0-in. (150 × 150 × 225-mm) concrete prisms of 6.0-ksi (41.0-MPa) compressive strength at 28 days shall be sand-blasted on one 6.0 × 6.0-in. (150 × 150-mm) side to remove mold release agent, laitance, etc., and shall be submerged in clean water at the lower temperature of the specified application temperature range for 72 h. Immediately on removing the concrete prisms from the water, the sandblasted surfaces shall be air-dried for 1 h at the same temperature and 50-percent relative humidity and each shall be coated with approximately a 0.0625-in (1.5-mm) layer of the mixed bonding agent. The adhesive-coated faces of two prisms shall then be placed together and held with a clamping force normal to the bonded interface of 0.05 ksi (0.35 MPa). The assembly shall then be wrapped in a damp cloth that is kept wet during the curing period of 24 h at the lower temperature of the specified application temperature range.

After 24 h curing at the lower temperature of the application temperature range specified for the epoxy-bonding agent, the bonded specimen shall be unwrapped, removed from the clamping assembly, and immediately tested. The test shall be conducted using the standard AASHTO T 97 (ASTM C 78) test for flexural strength with third-point loading and the standard MR unit. At the same time the two prisms are prepared and cured, a companion test beam shall be prepared of the same concrete, cured for the same period, and tested following AASHTO T 97 (ASTM C 78).

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

C8.13.7.1.4

The three-point tensile bending 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 6.0 × 6.0 × 18.0 in. (150 × 150 × 450 mm).

8.13.7.1.5 Test 5—Compression Strength of Cured Epoxy-Bonding Agent

Testing Method: ASTM D 695.

Specification: Compressive strength at 77°F (25°C) shall be a minimum of 2.0 ksi (14.0 MPa) after 24 h of curing at the minimum temperature of the designated application temperature range and 6.0 ksi (41.0 MPa) at 48 h.

C8.13.7.1.5

Compression strength test of cured epoxy-bonding agent measures the compressive strength of the epoxy-bonding agent.

8.13.7.1.6 Test 6—Temperature Deflection of Epoxy-Bonding Agent

Testing Method: ASTM D 648.

Specification: A minimum deflection temperature of 122°F (50°C) at fiber stress loading of 0.260 ksi (1.8 MPa) is required on test specimens cured seven days at 77°F (25°C).

C8.13.7.1.6

Temperature deflection test of epoxy-bonding agent 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.

8.13.7.1.7 Test 7—Compression and Shear Strength of Cured Epoxy-Bonding Agent

Testing Method: A test specimen of concrete is prepared in a standard 6.0 × 12.0-in. (150 × 300-mm) cylinder mold to have a height at midpoint of 6.0 in. (150 mm) 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 6.0 × 12.0-in. (150 × 300-mm) cylinder. If desired, 3.0 × 6.0-in. (75 × 150-mm) or 4.0 × 8.0-in. (100 × 200-mm) specimens may be used. After the specimens have been moist cured for 14 days, the slant surfaces shall be prepared by light sandblasting, stoning, or acid etching, then by washing and drying the surfaces, and finally by coating one of the surfaces with a 10-mil (0.25-mm) thickness of the epoxy-bonding agent under test. The specimens shall then be pressed together and held in position for 24 h. The assembly shall then be wrapped in a damp cloth that shall be kept wet during an additional curing period of 24 h at the minimum temperature of the designated application temperature range. The specimen shall then be tested at 77°F (25°C) following AASHTO T 22 (ASTM C 39/C 39M) procedures. At the same time as the slant cylinder specimens are made and cured, a companion standard test cylinder of the same concrete shall be made, cured for the same period, and tested following AASHTO T 22 (ASTM C 39/C 39M).

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

C8.13.7.1.7

Compression and shear strength test of cured epoxy-bonding agent 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.

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11.3.1.7 Structural Tubing

Structural tubing shall be either cold-formed welded or seamless tubing conforming to ASTM A 500, Grade B, or hot-formed welded or seamless tubing conforming to ASTM A 501.

11.3.2 High-Strength Fasteners

11.3.2.1 Material

High-strength bolts for structural steel joints shall conform to either AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) or AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)). When high-strength bolts are used with unpainted weathering grades of steel, the bolts shall be Type 3.

The supplier shall provide a lot of number appearing on the shipping package and a certification noting when and where all testing was done, including rotational capacity tests, and zinc thickness when galvanized bolts and nuts are used.

The maximum hardness for AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) bolts shall be 33 HRC.

Proof-load tests (ASTM F 606 (ASTM F 606M), Method 1) shall be required for the bolts. Wedge tests of full-size bolts are required in accordance with Section 8.3 of AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)). Galvanized bolts shall be wedge tested after galvanizing. Proof-load tests of AASHTO M 291 (ASTM A 563) (AASHTO M 291M (ASTM A 563M)) are required for the nuts. The proof-load tests for nuts to be used with galvanized bolts shall be performed after galvanizing, overtapping, and lubricating.

Except as noted below:

- Nuts for AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) bolts shall conform to AASHTO M 291 (ASTM A 563) (AASHTO M 291M (ASTM A 563M)), Grades DH, DH3, C, C3, and D (Property Class 8S, 8S3, 10S, or 10S3).

- Nuts for AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) bolts shall conform to the requirements of AASHTO M 291 (ASTM A 563) (AASHTO M 291M (ASTM A 563M), Grades DH and DH3 (Property Class 10S or 10S3)).

C11.3.2.1

Type 2 bolts have been withdrawn from AASHTO M 164 (ASTM A 325), AASHTO M 164M (ASTM A 325M), AASHTO M 253 (ASTM A 490), and AASHTO M 253M (ASTM A 490M) and, therefore, are no longer manufactured. However, Type 2 bolts manufactured before this discontinuation may still be in inventory and are considered acceptable.

Grade DH (Property Class 10S) nuts are recommended for all Type 1 and Type 2 bolts. Grade DH3 (Property Class 10S3) nuts are not recommended for Type 1 and Type 2 bolts. Grade DH3 (Property Class 10S3) nuts must be used for Type 3 bolts.

The exceptions are:

- Nuts to be galvanized (hot-dip or mechanically galvanized) shall be Grade DH (Property Class 10S).
- Nuts to be used with AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) Type 3 bolts shall be Grade C3 or DH3 (Property Class 8S3 or 10S3). Nuts to be used with AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)), Type 3 bolts shall be Grade DH3 (Property Class 10S3).

All galvanized nuts shall be lubricated with a lubricant containing a visible dye. Black bolts must be oily to touch when delivered and installed.

Washers shall be hardened steel washers conforming to the requirements of AASHTO M 293 (ASTM F 436) (AASHTO M 293M (ASTM F 436M)) and Article 11.5.6.4.3, "Requirements for Washers."

11.3.2.2 Identifying Marks

AASHTO M 164 (ASTM A 325) (AASHTO M 164M (ASTM A 325M)) for bolts and the specifications referenced therein for nuts require that bolts and nuts manufactured to the specification be identified by specific markings on the top of the bolt head and on one face of the nut. Head markings must identify the grade by the symbol "A 325" ("A 325M"), the Manufacturer, and the type, if Type 3. Nut markings must identify the property class, the Manufacturer, and, if Type 3, the type. Markings on direct tension indicators (DTI, ASTM F 959 (ASTM F 959M)) must identify the Manufacturer and Type "325" (Class "8.8"). Other washer markings must identify the Manufacturer, and, if Type 3, the type.

AASHTO M 253 (ASTM A 490) (AASHTO M 253M (ASTM A 490M)) for bolts and the specifications referenced therein for nuts require that bolts and nuts manufactured to the specifications be identified by specific markings on the top of the bolt head and on one face of the nut. Head markings must identify the grade by the symbol "A 490" ("A 490M"), the Manufacturer, and the type, if Type 3. Nut markings must identify the property class, the Manufacturer and if Type 3, the type. Markings on direct tension indicators must identify the Manufacturer and Type "490" (Class "10.9"). Other washer markings must identify the Manufacturer, and, if Type 3, the type.

11.8.6.2 Placement of Concrete

Concrete placements shall be made in the sequence specified in the approved construction plan. The time between placements shall be such that the concrete in prior pours has reached an age or strength specified in the construction plan. Any accelerating or retarding agents to be used in the concrete mix shall be specified.

The duration of each placement shall be specified in the construction plan. Placements that include both negative and positive dead load moment regions should be placed such that the positive moment region is poured first.

C11.8.6.2

When concrete is placed in a span adjacent to a span that already has a hardened deck, negative moment in the adjacent span causes tensile stresses and torsional shear stress in the cured concrete.

If long placements are made such that the negative moment region is poured first, it is possible that this region will harden and be stressed in tension during the remainder of the placement. This may cause early cracking of the deck.

It has been determined that placed concrete obtains composite action in a matter of hours. Therefore, the appropriate age and strength of the freshly placed concrete should be determined in part by the stress that will be induced during subsequent deck section placements.

11.8.7 Reports

Any modifications to the construction plan in the field from the original plan shall be documented with appropriate approvals noted.

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PRESERVATIVE TREATMENT OF WOOD

17.1 GENERAL

This work shall consist of treating wood, including lumber, timber, piles, and poles, with designated preservatives in accordance with these Specifications. It shall include furnishing, preparing, and treating all materials, and performing all work to complete treating the wood products required for the project.

The type of preservative treatment required shall be as specified in the contract documents.

When a specific type of preservative is not called for, the kind of preservative to be used shall be adopted for its suitability to the conditions of exposure to which it shall be subjected and shall be subject to approval of the Engineer.

The handling and care of treated woods shall conform to the requirements of Sections 4, "Driven Foundation Piles," and 16, "Timber Structures."

17.2 MATERIALS

17.2.1 Wood

Piling shall conform to the requirements of Section 4, "Driven Foundation Piles." Timber and lumber shall conform to the requirements of Section 16, "Timber Structures."

17.2.2 Preservatives and Treatments

Timber preservatives and treatment methods shall conform to AASHTO M 133. The type of preservative furnished shall be in accordance with that specified in the contract documents.

Unless otherwise specified in the contract documents, timber railings and posts and timber that are to be painted shall be treated with pentachlorophenol with a Type C solvent or with a water-borne preservative of either Type CCA or ACZA.

C17.2.2

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 in the contract documents, not less than the minimum retention is required.

17.2.3 Coal-Tar Roofing Cement

For purposes of these Specifications, pitch, coal-tar pitch, coal-tar roofing pitch, or coal-tar roofing compound shall mean coal-tar roofing cement wherever the terms are used.

C17.2.3

Coal-tar roofing cement is a residue of the manufacturing of coke and creosote from bituminous coal. It shall be a thick, heavy-bodied, and paste-like material. When called for, it can be mixed with creosote. It may or may not contain fibrous material.

17.3 IDENTIFICATION AND INSPECTION

17.3.1 Branding and Job Site 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. Treated wood products bearing the quality mark of the American Wood Preservers Bureau (AWPB) shall be acceptable. The Engineer shall be provided adequate facilities and free access to the necessary parts of the treating plant for inspection of material and work quality to determine that the contract document 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 documents, provided that, at the job site reinspection, conformance within five percent of contract document 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.

17.3.2 Inspection at Treatment Plant

Unless otherwise specified in the contract documents, inspection of materials and preservative treatment shall be the responsibility of the Contractor and the supplier of treated wood products. Inspections shall be conducted in accordance with AASHTO M 133 by the treater or an independent commercial inspection agency approved by the American Wood Preservers Bureau (AWPB) and the Engineer.

The inspection agency shall be engaged by the Contractor directly or through the Contractor's supplier. No direct compensation will be made for these inspection costs, it being understood that the costs of inspection shall be included in the contract bid prices for treated wood products or construction items of work.

C17.3.2

The AWPB "FDN" grademark is applied only to wood treated under the quality control provisions of the American Wood Preservers Bureau, P.O. Box 6085, 2772 South Randolph Street, Arlington, VA 22206. This grademark provides assurance that the products meet the treatment level required by the standards of the AWPB.

17.3.3 Certificate of Compliance

Whenever specified in the contract documents or requested by the Engineer, a Certificate of Compliance with copies of the inspection reports attached shall be furnished to the Engineer with each shipment of material. Such certificates shall identify the type of preservative used and the quantity in pounds per cubic foot (mass in kilograms per cubic meter) (assay method) and shall be signed by the treater or the qualified independent inspection agency.

REFERENCES

AASHTO. 2004. *AASHTO LRFD Bridge Design Specifications*, 3rd Edition, LRFDUS-3 or LRFDSI-3, American Association of State and Highway Transportation Officials, Washington, DC. Available in customary U.S. units or SI units.

AASHTO. 2004. *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 24th Edition, HM-24, American Association of State and Highway Transportation Officials, Washington, DC.

AASHTO and AWS. 2002. AASHTO/AWS D1.5M/D1.5 *Bridge Welding Code*, BWC-4, American Welding Society, Miami, FL.

ASME. 2002. *Surface Texture, Surface Roughness, Waviness and Lay*, B46.1, American Society of Mechanical Engineers, Fairfield, NJ.

RMA. 1992. *Rubber Handbook for Molded, Extruded, Lathe Cut and Cellular Products*, 5th Edition, Rubber Manufacturers Association, Inc., Washington, DC.

SAE. 1995. *Society of Automotive Engineers Specification Manual*, Volume 1, Society of Automotive Engineers, Warrendale, PA.

SAE. 2004. "Chemical Composition of SAE Carbon Steels," SAE J403, *SAE Handbook*, Society of Automotive Engineers, Warrendale, PA.

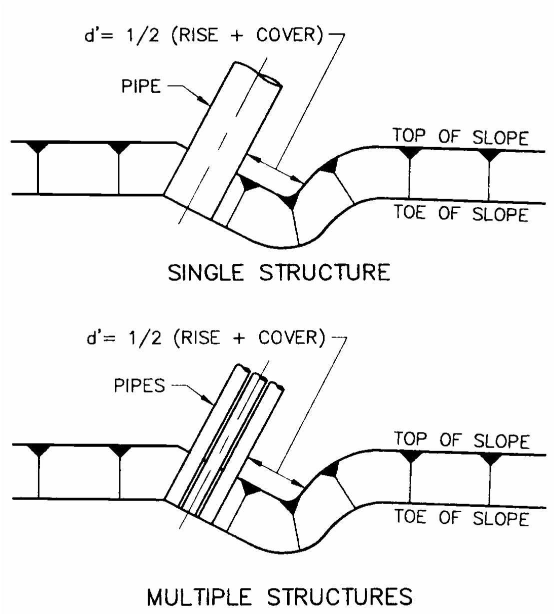


Figure 26.5.4.1-1 End Treatment of Skewed Flexible Culvert.

26.5.4.2 Arches

Arches may require special shape control during the placement and compaction of structure backfill.

Prior to construction, the Manufacturer shall attend a preconstruction conference to advise the Contractor(s) and Engineer of the more critical functions to be performed during backfilling and to present the intended quality control steps to be used to control loads, shape and movements.

C26.5.4.2

Pin connections at the footing restrict uniform shape change. Arches may peak excessively or experience curvature flattening in their upper quadrants during backfilling. Using lighter compaction equipment, more easily compacted structure backfill or top loading by placing a small load of structure backfill on the crown will aid installation.

26.5.4.3 Long-Span Structures

Prior to construction, the Manufacturer shall attend a preconstruction conference to advise the Contractor(s) and Engineer of the more critical functions to be performed during backfilling and to present the intended quality control steps to be used to control loads, shape and movements.

Equipment and construction procedures used to backfill long-span structural plate structures shall be such that excessive structure distortion will not occur. Structure shape shall be checked regularly during backfilling to verify acceptability of the construction methods used. Magnitude of allowable shape changes will be specified by the Manufacturer (Fabricator of long-span structures). The Manufacturer shall provide a qualified shape-control Inspector to aid the Engineer during the placement of all structure backfill to the minimum cover level over the structure. The shape-control Inspector shall advise the Construction Engineer on the acceptability of all backfill material and methods and the proper monitoring of the shape. Structure backfill material shall be placed in horizontal uniform layers not exceeding an 8.0-in.

C26.5.4.3

Backfill requirements for long-span structural-plate structures are similar to those for smaller structures. Their size and flexibility require special control of backfill and continuous monitoring of structure shape.

(200-mm) loose lift thickness and shall be brought up uniformly on both sides of the structure. Each layer shall be compacted to a density not less than 90 percent modified density per AASHTO T 180. The structure backfill shall be constructed to the minimum lines and grades shown in the contract documents, keeping it at or below the level of adjacent soil or embankment. The following exceptions to the required structure backfill density shall be permitted:

- the area under the invert,
- the 12.0-in. to 18.0-in. (300-mm to 450-mm) width of soil immediately adjacent to the large radius side plates of high-profile arches and inverted-pear shapes, and
- the lower portion of the first horizontal lift of overfill carried ahead of and under the small, tracked vehicle initially crossing the structure.

26.5.4.4 Box Culverts

A preconstruction conference on backfilling shall be required only when specified in the contract document or required by the Engineer. Shape control considerations should be similar to those needed for a metal culvert.

Structure backfill material shall be placed in uniform, horizontal layers not exceeding an 8-in. (200-mm) maximum loose lift thickness and compacted to a density not less than 90 percent modified density per AASHTO T 180. The structure backfill shall be constructed to the minimum lines and grades shown in the contract documents, keeping it at or below the level of the adjacent soil or embankment.

C26.5.4.4

Metal box culverts are not long-span structures because they are relatively stiff, semi-rigid frames.

26.5.5 Bracing

When required, temporary bracing shall be installed and shall remain in place as long as necessary to protect workers and to maintain structure shape during erection.

For long-span structures which require temporary bracing or cabling to maintain the structure in shape, the supports shall not be removed until the structure backfill is placed to an elevation to provide the necessary support. In no case shall internal braces be left in place when backfilling reaches the top quadrant of the pipe or the top radius arc portion of a long-span structure.

26.5.6 Arch Substructures and Headwalls

Substructures and headwalls shall be designed in accordance with the applicable requirements of *AASHTO LRFD Bridge Design Specifications*, 2004.

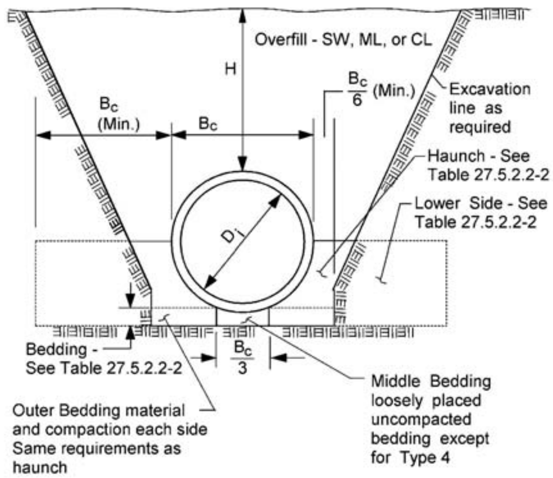
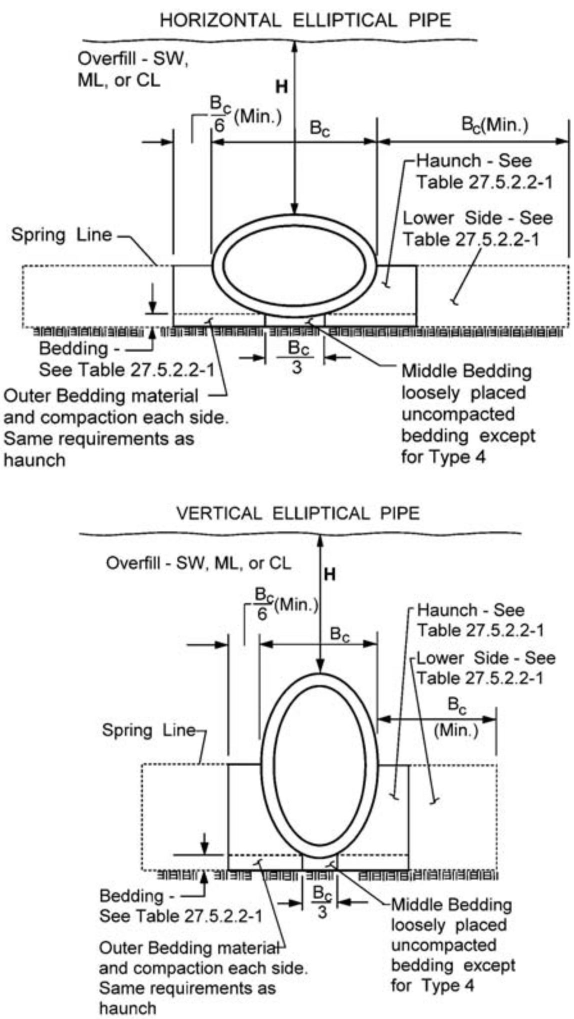


Figure 27.5.2.2-2 Standard Trench Installation—Round Pipe.



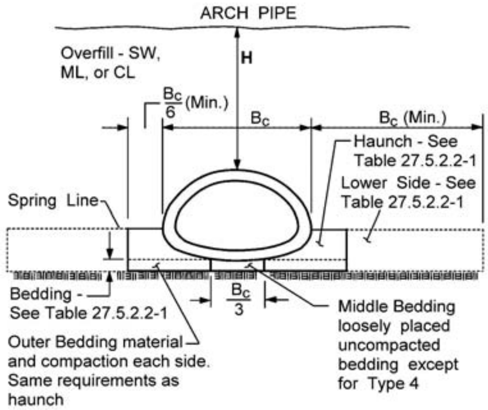
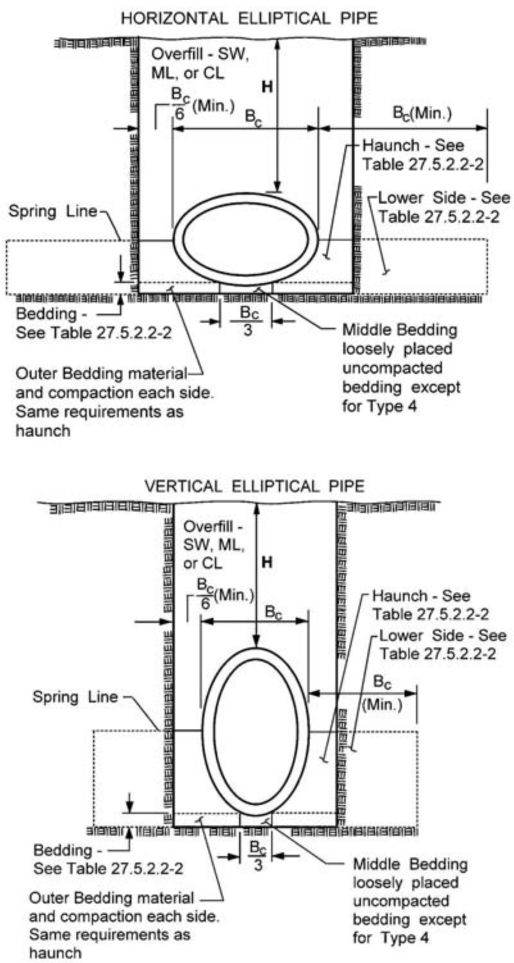
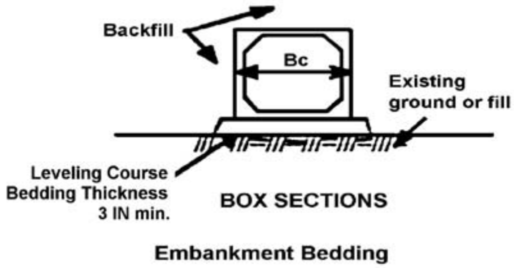


Figure 27.5.2.2-3 Embankment Beddings—Miscellaneous Shapes.





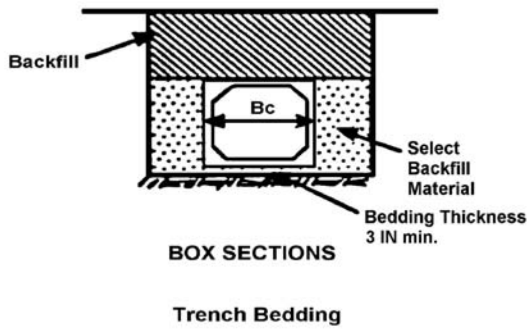


Figure 27.5.2.3-1 Bedding and Backfill Requirements.

27.5.3 Placing Culvert Sections

Unless otherwise authorized by the Engineer, the laying of culvert sections on the prepared bedding shall be started at the outlet and with the bell end pointing upstream and the spigot or tongue end pointing downstream and shall proceed toward the inlet end with the abutting sections properly matched, true to the established lines and grades. Where pipe with bells is installed, bell holes shall be excavated in the bedding to such dimensions that the entire length of the barrel of the pipe will be supported by the bedding when properly installed as shown in Figure 27.5.3-1. Proper facilities shall be provided for hoisting and lowering the sections of culvert into the trench without disturbing the prepared bedding and the sides of the trench. The ends of the section shall be carefully cleaned before the section is jointed. The section shall be fitted and matched so that when laid in the bed it shall form a smooth, uniform conduit. When elliptical pipe with circular reinforcing or circular pipe with elliptical reinforcing is used, the pipe shall be laid in the trench in such position that the markings “Top” or “Bottom,” shall not be more than five degrees from the vertical plane through the longitudinal axis of the pipe. Adjustments in grade by exerting force on the culvert with excavating equipment or by lifting and dropping the culvert shall be prohibited. If the installed culvert section is not on grade after joining, the section shall be completely unjoined, the grade corrected and the section rejoined.

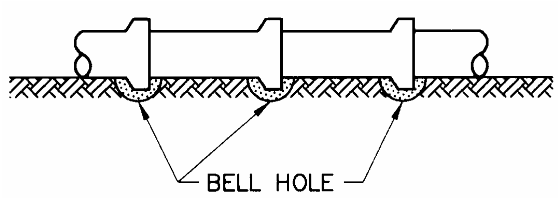


Figure 27.5.3-1 Excavation of Bell Holes for Uniform Support.

Multiple installations of reinforced concrete culverts shall be laid with the center lines of individual barrels parallel at the spacing shown in the contract documents. Pipe and box sections used in parallel installations require positive lateral bearing between the sides of adjacent pipe or box sections. Compacted earth fill, granular backfill, or grouting between the units are considered means of providing positive bearing.

27.5.4 Haunch, Lower Side, and Backfill or Overfill

27.5.4.1 Precast Reinforced Concrete Circular Arch and Elliptical Pipe

Haunch material, low side material, and overfill material shall be installed to the limits shown on Figures 27.5.2.2-1 through 27.5.2.2-4.

27.5.4.2 Precast Reinforced Concrete Box Sections

Backfill material shall be installed to the limits shown in Figure 27.5.2.3-1 for the embankment or trench condition.

C27.5.4.2

Although usually constructed with vertical walls, installation of precast box culverts in trenches with sloping sidewalls has not been a problem.

27.5.4.3 Placing of Haunch, Lower Side, and Backfill or Overfill

Fill material shall be placed in layers with a maximum loose thickness of 8.0 in. (200 mm) and compacted to obtain the required density. The fill material shall be placed and compacted with care under the haunches of the culvert and shall be raised evenly and simultaneously on both sides of the culvert. For the lower haunch areas of Type 1, 2, and 3 Standard Installations, soils requiring 90 percent or greater standard proctor densities shall be placed in layers with a maximum thickness of 8.0 in. (200 mm) and compacted to obtain the required density. The width of trench shall be kept to the minimum required for installation of the culvert. Ponding or jetting will be only by the permission of the Engineer.

C27.5.4.3

Generally, compaction of fill material to the required density is dependent on the thickness of the layer of fill being compacted, soil type, soil moisture content, type of compaction equipment, and amount of compactive force and length of time the force is applied.

REFERENCES

AASHTO. 2000. *Highway Drainage Guidelines, Volume XIV: Culvert Inspection, Material Selection, and Rehabilitation*, HDGV14-3, American Association of State Highway and Transportation Officials, Washington, DC.

AASHTO. 2004. *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 24th Edition, HM-24, American Association of State Highway and Transportation Officials, Washington, DC.

USACE. 1953. *The Unified Soil Classification System*, Waterways Experimental Station Technical Member 3-357, Vicksburg, MS, USACE Publication Depot, Hyattsville, MD.

SECTION 29

EMBEDMENT ANCHORS

29.1 DESCRIPTION

This work shall cover installation and field testing of cast-in-place, grouted, adhesive-bonded, expansion, and undercut steel anchors.

C29.1

The use of embedment anchors is prevalent but standardized installation and field testing is not. Therefore, a new section was created.

29.2 PREQUALIFICATION

Concrete anchors, including cast-in-place; all bonded anchor systems, including grout, chemical compound and adhesives; and undercut steel anchors shall be prequalified by universal test standards designed to allow approved anchor systems to be employed for any construction attachment use.

Tests for adhesive-bonded and other bonding compounds shall be conducted in accordance with ASTM E 1512, Standard Test Methods for Testing Bond Performance of Adhesive-Bonded Anchors.

Expansion anchors shall be tested in accordance with ASTM E 488, Standard Test Methods for Strength of Anchors in Concrete and Masonry Elements.

Embedment anchor details shall comply with ACI 349, *Code Requirements for Nuclear Safety Related Concrete Structures*, "Appendix B, Steel Embedments."

For anchor systems other than mechanical expansion anchors, the Contractor shall provide the Engineer with certified test reports prepared by an independent laboratory documenting that the system is capable of achieving the minimum tensile strength of the embedment steel.

29.3 MATERIALS

Mill test reports shall be provided to the Engineer to certify physical properties, chemistry, and strengths used to manufacture the anchors.

Either an epoxy, vinylester, or polyester chemical compound shall be acceptable for adhesive anchors. Moisture-insensitive, high-modulus, low shrinkage, and high-strength adhesives shall be used.

The use of additives to grout and bonding materials that are corrosive to steel or zinc/cadmium coatings shall be prohibited.

29.4 CONSTRUCTION METHODS

Adequate edge distance, embedment depth, and spacing to develop the required strength of the embedment anchors shall be provided. The correct drill-hole diameter shall be used as specified by the Manufacturer. Rotary impact drilling shall be used unless diamond core drilling has been specified or tested. If a reinforcing bar is encountered during drilling, the hole shall be moved to a different location or the reinforcing steel shall be drilled through using a diamond core bit as directed by the

Engineer. Abandoned holes shall be patched with an approved bonding material. Holes shall be thoroughly cleaned as recommended by the Manufacturer.

The Contractor shall remove all loose dust and concrete particles from the hole and shall prepare bonding material and install anchors according to the Manufacturer's instructions or as approved by the Engineer.

Improperly installed embedded anchors or anchors not having the required strength shall be removed and replaced to the satisfaction of the Engineer at the Contractor's expense.

29.5 INSPECTION AND TESTING

Where specified, sacrificial tests of the anchor system shall be done at the job site to ultimate loads to document the capability of the system to achieve pullout loads equaling the full minimum tensile value of the anchor employed. Anchor testing shall be done on fully cured concrete samples. At least three anchors shall be tested by ASTM E 488 methods, unless otherwise specified. The Contractor may use any prequalified anchor systems meeting the above requirements.

Provision shall be made for use of an alternative system that will reach the designated pullout requirement, without delay in progress, if the job site proof loading proves incapable of achieving minimum tensile values, or the load required by the Engineer if too little concrete exists in which to develop full ductile loads.

After installation and cure of the bonding material, each anchor system shall be torqued to specified values using approved torque methods only. If torque values are not specified, the Manufacturer's recommendation or values provided by the Engineer shall be used.

29.6 MEASUREMENT

Measurement of embedment anchors incorporated into the project shall be the number of each anchor size and orientation shown in the contract documents or authorized for use on the project. Each embedment anchor type satisfactorily installed shall be counted and summarized in the contract documents according to anchor system; orientation, i.e., vertical, horizontal, and diagonal; and size taken as the diameter.

29.7 PAYMENT

Payment shall be based upon the quantity of embedment anchors determined under measurement for each embedment anchor type and shall include full compensation for furnishing all labor, materials, tools, equipment, testing, and incidentals necessary to place each anchor type.

REFERENCES

ACI. 2001. *Code Requirements for Nuclear Safety Related Concrete Structures*, ACI 349-01, American Concrete Institute, Farmington Hills, MI, Appendix B: Steel Embedments.

- Bell and spigot pipe ends (with or without gaskets)
- Double bell couplings (with or without gaskets)

30.5 INSTALLATION

30.5.1 General Installation Requirements

Trenches shall be excavated in such a manner as to ensure that the sides will be stable under all working conditions. Trench walls shall be sloped or supported in conformance with all standards of safety. Only as much trench as can be safely maintained shall be opened. All trenches shall be backfilled as soon as practicable, but not later than the end of each working day.

Trench details, including foundation, bedding, haunching, initial backfill, final backfill, pipe zone, and trench width shall be taken as shown in Figure 30.5-1.

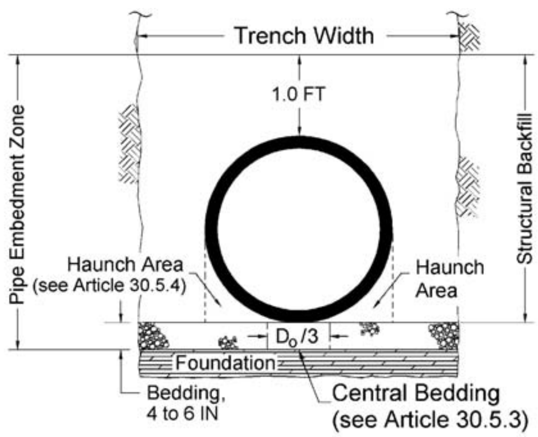


Figure 30.5.1-1 Trench Details.

30.5.2 Trench Widths

Trench width shall be sufficient to ensure working room to properly and safely place and compact haunching and other backfill materials. The space between the pipe and trench wall should be wider than the compaction equipment used in the pipe zone. Minimum trench width shall not be less than 1.5 times the pipe outside diameter plus 12.0 in. (300 mm). Determination of trench width in unsupported, unstable soils shall include consideration of the size of the pipe, the stiffness of the backfill and in situ soil, the depth of cover and other site-specific conditions as applicable. The trench shall be excavated to the width, depth, and grade as indicated on the plans and/or given by the Engineer.

30.5.3 Foundations and Bedding

Foundation and bedding shall meet the requirements of Article 30.3.2 and shall be installed as required by the

Engineer according to conditions in the trench bottom. A stable and uniform bedding shall be provided for the pipe and any protruding features of its joint and/or fittings. The middle of the bedding equal to one-third the pipe outside diameter (OD) should be loosely placed, while the remainder shall be compacted to a minimum 90 percent of maximum density per AASHTO T 99. A minimum of 4.0 in. (100 mm) of bedding shall be provided prior to placement of the pipe unless otherwise specified.

When rock or unyielding material is present in the trench bottom, a cushion of bedding of 6.0 in. (150 mm) minimum thickness shall be provided below the bottom of the pipe.

When the trench bottom is unstable, material shall be excavated to the depth required by the Engineer, and replaced with a suitable foundation. A suitably graded material shall be used where conditions may cause migration of fines and loss of pipe support.

30.5.4 Structural Backfill

Structural backfill shall meet the requirements of Article 30.3.2. Structural backfill shall be placed and compacted in layers not exceeding an 8.0-in. (200-mm) loose lift thickness and brought up evenly and simultaneously on both sides of the pipe to an elevation not less than 1.0 ft (300 mm) above the top of the pipe. Structural backfill shall be worked into the haunch area and compacted by hand.

A minimum compaction level of 90 percent standard density per AASHTO T 99 shall be achieved. Special compaction means may be necessary in the haunch area as shown in Figure 30.5.4-1. All compaction equipment used within 3.0 ft (900 mm) of the pipe shall be approved by the Engineer. Ponding or jetting the structural backfill to achieve compaction shall not be permitted without written permission from the Engineer.

Backfill materials placed in the zone extending more than 1.0 ft (300 mm) above the pipe to final grade shall be selected, placed, and compacted to satisfy the loading, pavement, and other requirements above the pipe.

30.5.5 Minimum Cover

A minimum depth of cover above the pipe should be maintained before allowing vehicles or heavy construction equipment to traverse the pipe trench. The minimum depth of cover should be established by the Engineer based on an evaluation of specific project conditions. For embedment materials installed to the minimum density given in Article 30.5.4, "Structural Backfill," cover of at least 2.0 ft (600 mm) shall be provided before allowing vehicles or construction equipment to cross the trench surface. Minimum cover for construction loads shall be as shown in Table 30.5.5-1. Hydrohammer type compactors shall not be used over the pipe.

C30.5.5

Diameters greater than 4.0 ft (1200 mm) in Table 30.5.5-1 are for information only. See Tables A12-11, A12-12, and A12-13 of the *AASHTO LRFD Bridge Design Specifications* for nominal sizes.

31.4 FABRICATION

31.4.1 Identification of Aluminum Alloys During Fabrication

The Contractor shall issue cutting instructions and mark individual pieces so as to be able to identify the material used for each piece. Metal stamping marks, scribe lines, and center punch marks shall not be used where they will remain on fabricated material.

The Contractor may furnish material that can be identified by lot and mill test report from stock.

During fabrication prior to assembly, each piece shall clearly show its material specification. Writing the material specification number on the piece or by using the identification color codes shown in Table 31.4.1-1 shall be taken as compliance with this provision.

Table 31.4.1-1 Identification Color Codes.

Alloy	Color
5083	Red and Gray
5086	Red and Orange
6061	Blue
6063	Yellow and Green

Aluminum alloys not listed in Table 31.4.1-1 shall be marked with colors listed in *Aluminum Standards and Data*.

Any piece which will be subject to fabrication that might obscure its identification prior to assembly shall have a substantial tag affixed showing the material specification number.

Upon request by the Engineer, the Contractor shall furnish an affidavit certifying that the identification of pieces has been maintained in accordance with this specification.

C31.4.1

Aluminum Standards and Data gives color codes for additional alloys and other information on identification marking used by aluminum producers in Section 4.

31.4.2 Storage of Materials

Material shall be stored out of contact with the ground, free from dirt, grease, and foreign matter and out of contact with dissimilar materials such as uncoated steel.

31.4.3 Plates

31.4.3.1 Direction of Rolling

Unless otherwise specified in the contract documents, plates for main members and splice plates for flanges and main tension members, i.e., 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.

31.4.3.2 Plate Edges

Plates more than 0.5 in. (12 mm) thick carrying calculated stress shall not be sheared. All edges that have been cut by the arc process shall be planed to remove edge cracks. Oxygen cutting shall not be used. Re-entrant corners shall be filleted to a radius of 0.75 in. (20 mm) or more.

31.4.3.3 Bent Plates

31.4.3.3.1 General

Bend lines in unwelded, load-carrying, rolled aluminum plates shall be perpendicular to the direction of rolling.

Before bending, the corners of the plates shall be rounded to a radius of 0.0625 in. (1.5 mm) throughout the portion of the plate over which the bending is to occur.

31.4.3.3.2 Cold Bending

Cold bending shall not produce cracking. For 90-degree bends, bend radii measured to the concave face of the metal shall not be less than those listed in Table 31.4.3.3.2-1.

C31.4.3.3.2

Recommended bend radii for 90-degree cold bends for other alloys may be found in Table 7.6 of *Aluminum Standards and Data, 2003 (Metric SI)*.

Table 31.4.3.3.2-1 Minimum Bend Radii (in.) for 90-Degree Bends.

Alloy	Plate Thickness, in.			
	0.1875	0.25	0.375	0.5
5083-H321	0.28	0.35	0.79	1.77
5086-H116	0.28	0.47	0.98	1.42
5456-H116	0.38	0.59	1.18	1.65
6061-T6	0.55	0.83	1.77	2.36

31.4.4 Fit of Stiffeners

End bearing stiffeners for girders and stiffeners intended as supports for concentrated loads shall bear fully on the flanges to which they transmit load or from which they receive load. Intermediate stiffeners not intended to support concentrated loads shall have a tight fit against the compression flange, unless specified otherwise.

C31.4.4

Full bearing may be obtained by milling, grinding, or in the case of compression regions of flanges, by welding.

31.4.5 Abutting Joints

Abutting ends of compression members of trusses and columns shall be milled or saw-cut to give a square joint and uniform bearing. At other joints, the distance between adjacent members shall not exceed 0.375 in. (10 mm).

31.4.11 Aluminum Bridge Decks

31.4.11.1 General

Dimensional tolerances specified below for aluminum bridge deck panels shall be applied to each completed, but unloaded panel. The deviation from detailed flatness, straightness, or curvature at any point shall be the perpendicular distance from that point to a template edge which has the detailed straightness or curvature and which is in contact with the panel at two other points. The template edge may have any length not exceeding the lesser of the greatest dimension of the panel and 1.5 times the least dimension of the panel; it may be placed anywhere on the panel. The distance between adjacent points of contact of the template edge with the panel shall be used in the formulas to establish the tolerances for the panel whenever this distance is less than the applicable dimension of the panel specified for the formula.

31.4.11.2 Flatness of Panels

The deviation, δ, from detailed flatness or curvature of a panel shall not exceed:

$$\delta \leq \frac{D}{144\sqrt{T}} \leq 0.1875 \text{ in.} \qquad (31.4.11.2\text{-}1)$$

where:

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

T = the minimum thickness of the top flange of the panel, in.

31.4.11.3 Straightness of Longitudinal Stiffeners Subject to Calculated Compressive Stress

The deviation, δ, from detailed straightness or curvature in any direction perpendicular to the length of a longitudinal stiffener subject to calculated compressive stress shall not exceed:

$$\delta \leq \frac{L}{480} \qquad (31.4.11.3\text{-}1)$$

where:

L = the length of the stiffener over which the deviation in detailed straightness or curvature is measured, in. (mm)

31.4.11.4 Straightness of Transverse Web Stiffeners and Stiffeners Not Subject to Calculated Compressive Stress

The deviation, δ, from detailed straightness or curvature in any direction perpendicular to the length of a transverse stiffener or a stiffener not subject to calculated compressive stress shall not exceed:

$$\delta \leq \frac{L}{240} \tag{31.4.11.4-1}$$

where:

L = the length of the stiffener over which the deviation in detailed straightness or curvature is measured, in. (mm)

31.4.12 Full-Size Tests

When full-size tests of fabricated structural members are required in the contract documents, the Contractor shall provide suitable facilities, material, supervision, and labor necessary for making and recording the required tests. The members tested shall be paid for in accordance with Article 31.7.2, "Basis of Payment."

31.4.13 Marking and Shipping

Each member shall be painted or marked with an erection mark for identification and an erection diagram showing these marks shall be furnished to the Engineer. Metal stamping shall not be used to mark aluminum parts.

The Contractor shall furnish to the Engineer as many copies of material orders, shipping statements, and erection diagrams as the Engineer may direct. The weight (mass) of the individual members shall be shown on the statements. Members having a weight (mass) of more than 6.5 kips (3000 kg) shall have the weight (mass) marked on them. Structural members shall be loaded on trucks or cars in such a manner that they may be transported and unloaded at their destination without being damaged.

Bolts, nuts, and washers from each rotational-capacity lot shall be shipped in the same container. If there is only one production lot number for each size of nut and washer, the nuts and washers may be shipped in separate containers. The gross weight (mass) of any container shall not exceed 0.3 kips (140 kg). A list showing the quantity and description of materials shall be plainly marked on the outside of each container.

31.5.3.2 Field Bolted Connections

Major compression members with milled ends shall be assembled in full bearing and then shall have their subsized holes reamed to the specified size while the members are assembled.

31.5.3.3 Check Assemblies for Numerically-Controlled Fabrication

Unless otherwise stated in the contract documents, when the Contractor elects to use numerically controlled hole fabrication, a check assembly shall be provided for each major structural type of each project. Except as noted herein, the check assembly shall consist of at least three contiguous shop sections. In a truss, the check assembly shall consist of 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 shall be assembled in accordance with the sequence shown on the erection drawings. If the check assembly fails to demonstrate that the required accuracy is being obtained, further check assemblies may be required by the Engineer at no additional cost to the Owner.

Each check assembly and its camber, alignment, accuracy of holes, and fit of milled joints shall be approved by the Engineer before reaming is commenced or before the check assembly is dismantled.

31.5.3.4 Field-Welded Connections

For field-welded connections, the fit of members, including the proper space between abutting members, shall be prepared or verified with the segment preassembled in accordance with Article 31.5.3.1.

31.5.4 Match-Marking

Connecting parts preassembled in the shop to assure proper fit in the field shall be match-marked, and a diagram showing such marks shall be furnished to the Engineer.

31.5.5 Welding

Brackets, clips, shipping devices, or other material not required by the contract documents shall not be welded or tacked to any member unless specified in the contract documents and approved by the Engineer.

31.6 ERECTION

31.6.1 General

The Contractor shall provide all tools, machinery, and equipment necessary to erect the structure.

31.6.2 Handling and Storing Materials

Material to be stored at the job site shall be placed on skids above the ground and kept clean and well drained. Girders and beams shall be placed upright and shored. If the Contractor's scope of work is for erection only, the Contractor shall check the material received against the shipping lists and report promptly in writing any shortage or damage. After material is received by the Contractor, the Contractor shall be responsible for any damage to or loss of material.

C31.6.2

Where moisture is trapped between adjacent surfaces of closely packed aluminum, white or gray stains, referred to as water stains, may result. Alloys having a high magnesium content are affected to a greater degree, but all aluminum alloys can be affected. Water staining is a superficial condition and does not affect the strength of the material, nor will it progress once the conditions that caused it are removed. It can be avoided by keeping the material dry.

31.6.3 Bearings and Anchorages

Bridge bearings shall be furnished and installed in conformance with Section 18, “Bearing Devices.”

If the aluminum superstructure is to be placed on a substructure that was built under a separate contract, the Contractor shall verify that the substructure has been constructed in the right location and to the correct lines and elevations before ordering materials.

31.6.4 Erection Procedure

31.6.4.1 Conformance to Erection Drawings

The erection procedure shall conform to the erection drawings submitted in accordance with Article 31.2.2, “Erection Drawings.” Any modifications to or deviations from this erection procedure shall require revised drawings and verification of stresses and geometry.

31.6.4.2 Erection Stresses

Any erection stresses induced in the structure as a result of erection which differs from the contract documents shall be accounted for by the Contractor. Erection design calculations for such changed methods shall be prepared at the Contractor's expense and submitted to the Engineer. The calculations shall indicate any change in stresses or change in behavior for the temporary and final structures. Additional material required to keep both the temporary and final force effects within the limits used in design shall be provided at the Contractor's expense.

The Contractor shall be responsible for providing temporary bracing or stiffening devices to limit stresses in individual members or segments of the structure during erection.

When tests of full-sized members are required by the contract documents, payment for tested members shall be made at the same rate as for comparable members for the structure. The cost of testing, including equipment, labor, and incidentals, shall be included in the contract price for structural aluminum. The cost of members which fail to meet the contract document requirements, and members rejected as a result of tests, shall be borne by the Contractor.

REFERENCES

AASHTO. 1991. *Guide Specifications for Aluminum Highway Bridges*, GSAHB-1, American Association of State Highway and Transportation Officials, Washington, DC.

AASHTO. 2004. *AASHTO LRFD Bridge Design Specifications*, 3rd Edition, LRFDUS-3 or LRFDSI-3, American Association of State and Highway Transportation Officials, Washington, DC. Available in customary U.S. units or SI units.

AASHTO and AWS. 2002. AASHTO/AWS D1.5M/D1.5 *Bridge Welding Code*, BWC-4, American Welding Society, Miami, FL.

AISC Quality Certification Program, American Institute of Steel Construction, Chicago, IL, Category I: Structural Steel and Category III: Fracture-Critical. See http://www.aisc.org.

Aluminum Association. 2003. *Aluminum Standards and Data 2003 (Metric SI)*, Aluminum Association, Washington, DC.

ASME. 1979. *Metric Heavy Hex Nuts*, B18.2.4.6M, American Society of Mechanical Engineers, Fairfield, NJ. Reaffirmed 1998.

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ASME. 1996. *Square and Hex Bolts and Screws, Inch Series*, B18.2.1, American Society of Mechanical Engineers, Fairfield, NJ.

ASME. 2002. *Surface Texture, Surface Roughness, Waviness and Lay*, B46.1, American Society of Mechanical Engineers, Fairfield, NJ.

AWS. 2003. ANSI/AWS D1.2/D1.2M *Structural Welding Code—Aluminum*, American Welding Society, Miami, FL.

DOD. U.S. Military Specification MIL-P-23469D for aluminum, stainless steel, and steel lock-pin and collar fasteners, U.S. Department of Defense, Washington, DC. See http://assist.daps.dla.mil/quicksearch/.

DOD. U.S. Military Specification MIL-R-1150F for rivets, U.S. Department of Defense, Washington, DC. See http://assist.daps.dla.mil/quicksearch/.

- Every 6 y, or as determined by the Owner, notify maintenance forces to unclasp the protective boot and examine the condition of the piston rod, as well as determine if there is evidence of leakage of the internal fluid.

- Every 10 y, notify maintenance forces to load STU(s) as selected by the Owner, and in a manner to ensure the STU can develop the rated load.

32.6 MEASUREMENT AND PAYMENT

STUs shall be measured and paid for by the number of units installed and accepted as shown in the contract documents or ordered by the Engineer.

The contract unit price paid for STUs shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals; and for doing all the work involved in installing STUs (including testing), complete in place, as specified in these Specifications, the contract documents, and as directed by the Engineer.

C32.6

Some agencies prefer to pay for testing separately, especially if waiver of testing is a consideration.

REFERENCES

AASHTO. 2004. *AASHTO LRFD Bridge Design Specifications*, 3rd Edition, LRFDUS-3 or LRFDSI-3, American Association of State and Highway Transportation Officials, Washington, DC. Available in customary U.S. units or SI units.

AASHTO. 2004. *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 24th Edition, HM-24, American Association of State Highway and Transportation Officials, Washington, DC.

Highway Innovative Technology Evaluation Center (HITEC), a service center of the Civil Engineering Research Foundation (CERF).

SAE. 2004. "Chemical Composition of SAE Carbon Steels," SAE J403, *SAE Handbook*, Society of Automotive Engineers, Warrendale, PA.

SI VERSIONS OF EQUATIONS, TABLES, AND FIGURES

SECTION 4

$$P_n = \frac{(0.6)1635\,W\,H}{(S + 25)} \qquad (4.4.4.2\text{-}1)$$

The factor 10 in Eq. 1 is the gravitational acceleration rounded to an even number.

$$P_n = \frac{(0.6)166.7\,E}{(S + 2.5)} \qquad (4.4.4.2\text{-}2)$$

where:

P_n = unfactored, i.e., nominal, bearing capacity, N

W = mass of striking parts of the hammer, kg

H = height of fall, m

E = energy produced by the hammer per blow in joules, J. Value based on actual hammer stroke or bounce chamber pressure observed (double acting diesel hammer).

S = the average penetration in mm per blow for the last five to ten blows for gravity hammers and the last ten to 20 blows for all other hammers.

$$S_f = S + (3.8 + 0.008D) \qquad (4.4.4.5\text{-}1)$$

where:

S_f = settlement at failure, mm

D = pile diameter or width, mm

S = elastic deformation of total unsupported pile length, mm

SECTION 5

Table 5.4.11-1 Range of Values at 20°C.

Property, Units	At Time of Slurry Introduction	At Time of Concerting (In Hole)	Test Method
Density, kg/m^3	1030 to 1110	1030 to 1200	Density Balance
Viscosity, s/L	30 to 48	30 to 48	Marsh Cone
pH	8 to 11	8 to 11	pH Paper or Meter

SECTION 8

Table 8.2.2-1 Classification of Normal-Density Concrete.

Class of Concrete	Minimum Cement Content	Maximum Water/ Cementitious Material Ratio	Air Content Range	Size of Coarse Aggregate Per AASHTO M 43 (ASTM D 448)	Size Number [a]	Specified Compressive Strength
	kg/m^3	kg per kg	%	Nominal Size, mm		MPa at days
A	362	0.49	—	25.0 to 4.75	57	28 at 28
A(AE)	362	0.45	6 ± 1.5	25.0 to 4.75	57	28 at 28
B	307	0.58	—	50 to 25.0 and 25.0 to 4.75	3 57	17 at 28
B(AE)	307	0.55	5 ± 1.5	50 to 25.0 and 25.0 to 4.75	3 57	17 at 28
C	390	0.49	—	12.5 to 4.75	7	28 at 28
C(AE)	390	0.45	7 ± 1.5	12.5 to 4.75	7	28 at 28
P	334	0.49	— [b]	25.0 to 4.75 or 19.0 to 4.75	7 67	≤ 41 at [b]
S	390	0.58	—	25.0 to 4.75	7	-
P(HPC)	— [c]	0.40	— [b]	≤ 19.0	67	> 41 at [b]
A(HPC)	— [c]	0.45	— [b]	— [c]	— [c]	≤ 41 at [b]

[a] As noted in AASHTO M 43 (ASTM D 448), Table 1–Standard Sizes of Processed Aggregate.
[b] As specified in the contract documents.
[c] Minimum cementitious materials content and coarse aggregate size to be selected to meet other performance criteria specified in the contract.

Table 8.4.2-1 Normal-Density Concrete Slump Test Limits.

Type of Work	Nominal Slump, mm	Maximum Slump, mm
Formed Elements: Sections over 300 mm Thick Sections 300 mm Thick or Less	 25–75 25–100	 125 125
Cast-in-Place Piles and Drilled Shafts Not Vibrated	125–200	225
Concrete Placed under Water	125–200	225
Filling for Riprap	75–175	200

SECTION 16

Table 16.2.6.1-1a Typical Dimensions of Timber Connectors.

Split Rings		
	65 mm	100 mm
Split Ring:		
Inside Diameter at Center When Closed	63.5	101.6
Thickness of Metal at Center	4.1	4.9
Depth of Metal (Width of Ring)	19.1	25.4
Groove:		
Inside Diameter	65.0	103.6
Width	4.6	5.3
Depth	9.5	12.7
Bolt Diameter (Size):	12.7	M20
Hole Diameter	14.3	20.6
Washers, Standard:		
Round, Cast or Malleable Iron,		
Diameter	66.7	76.2
Round, Mild Steel,		
Diameter	34.9	50.8
Thickness	2.4	4.0
Square Plate, Mild Steel		
Length of Side	50.8	76.2
Thickness	3.2	4.8

Table 16.2.6.1-1b Typical Dimensions of Timber Connectors.

Shear Plates, mm				
	66.7	66.7	101.6	101.6
Shear Plate:				
Material	Pressed Steel	Light Gauge	Malleable	Malleable
Diameter of Plate	66.5	66.5	102.4	102.4
Diameter of Bolt Hole	20.6	20.6	20.6	23.9
Thickness of Plate	4.4	3.0	5.1	5.1
Depth of Flange	10. 7	8. 9	16.3	16.3
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	20.6	20.6	20.6	23.8
Circular Dap—Dimensions:				
A	66.8	66.8	102.4	102.4
B	—	27.18	39.4	39.4
C	20.6	20.6	20.6	23.9
D	—	16.5	24.6	24.6
E	4.8	3.3	6.9	6.9
F	11.4	9.7	16.3	16.3
G	6.3	3.6	5.6	5.6
H	—	8.6	12.7	12.7
I	57.1	60.2	88.6	88.6
Bolt Hole—Diameter in Timber	20.6	20.6	20.6	23.8
Washers, Standard:				
Round, Cast, or Malleable Iron Diameter	76.2	76.2	76.2	88.9
Round, Medium Steel, minimum				
Diameter	50.8	50.8	50.8	57.1
Thickness	3.9	3.9	3.9	4.4
Square Plate:				
Length of Side	76.2	76.2	76.2	76.2
Thickness	6.3	6.3	6.3	6.3

SECTION 30

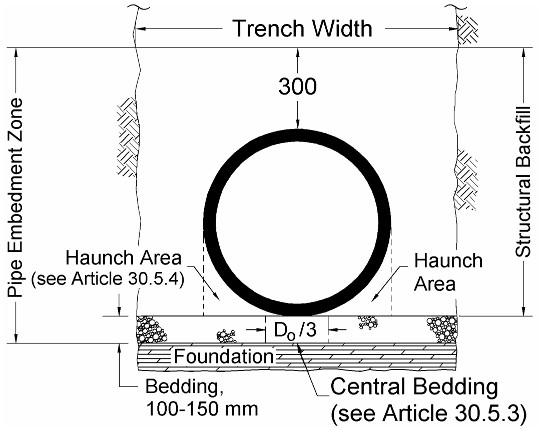

Figure 30.5.1-1 Trench Details.

Table 30.5.5-1 Minimum Cover for Construction Loads.

	Minimum Cover, mm, for Indicated Axle Loads, kN			
Nominal Pipe Diameter, mm	80–220	220–330	330–490	490–670
600–915	600	750	900	900
1050–1220	900	900	1050	1200
1350–1525	900	900	1050	1200

SECTION 31

Table 31.4.3.3.2-1 Minimum Bend Radii, mm, for 90-Degree Bends.

Alloy	Plate Thickness, mm			
	5	6	10	12
5083-H321	7	9	20	30
5086-H116	7	12	25	36
5456-H116	10	15	30	42
6061-T6	14	21	45	60

$$\delta \leq \frac{D}{28\sqrt{T}} \leq 5 \text{ mm} \qquad (31.4.11.2\text{-}1)$$

where:

D = the least dimension along the boundary of the panel, mm

T = the minimum thickness of the top flange of the panel, mm

Table 31.7.1-1 Mass Densities of Aluminum Alloys.

Alloy	Mass Density, kg/m^3
5083	2660
5086	2660
5456	2660
6061	2710
6063	2690