SECTION 26

METAL CULVERTS

26.1—GENERAL

26.1.1—Description

This work shall consist of furnishing, fabricating, installing, and inspecting metal pipe, structural plate metal pipe, arches, pipe arches, box structures, and deep corrugated structures in conformance with these Specifications, and the details shown in the contract documents. As used in this specification, long-span structures are metal plate horizontal elliptic, inverted pear and multiple radius arch shapes, as well as special shape culverts as defined in Section 12 of the *AASHTO LRFD Bridge Design Specifications*.

C26.1.1

The terms "metal pipe" and "metal structural plate pipe" includes circular and pipe arch, underpass and elliptical shapes. "Metal structural plate arches" consist of a metal plate arch supported on reinforced concrete footings with or without a paved invert slab. "Pipe arches" are constructed to form a pipe having an arch-shaped crown and a relatively flat invert. "Structural plate metal box structures" are conduits, rectangular in cross-section, constructed of metal plates.

The metal culvert description refers to Section 12, "Buried Structures and Tunnel Liners," of the *AASHTO LRFD Bridge Design Specifications*.

26.2—WORKING DRAWINGS

Where specified or requested by the Engineer, the Contractor shall provide Manufacturer's installation instructions or working drawings and substantiating calculations in sufficient detail to permit a structural review. The working drawings shall be submitted in advance of construction to allow for their review, revision, and approval without delay to the work.

The Contractor shall not start the construction of any metal culvert for which working drawings are required until the drawings have been approved by the Engineer. Such approval will not relieve the Contractor of responsibility for results obtained by use of these drawings or any other contractual responsibilities.

26.3—MATERIALS

26.3.1—Corrugated Metal Pipe

Steel pipe shall conform to the requirements of AASHTO M 36 (ASTM A760/A760M).

Aluminum pipe shall conform to the requirements of AASHTO M 196 (ASTM B745/B745M).

26.3.2—Structural Plate

Steel structural plate shall conform to the requirements of AASHTO M 167M/M 167 (ASTM A761/A761M).

Aluminum alloy structural plate shall conform to the requirements of AASHTO M 219 (ASTM B746/B746M).

26.3.3—Nuts and Bolts

Nuts and bolts for steel structural plate pipe, arches, pipe arches, and box structures shall conform to the requirements of AASHTO M 167M/M 167 (ASTM A761/A761M). Nuts and bolts for aluminum structural plate shall be aluminum conforming to the requirements of ASTM F468 or standard strength steel conforming to ASTM A307.

26.3.4—Mixing of Materials

Aluminum and steel materials shall not be mixed in any installation unless the materials are adequately separated or protected to avoid galvanic reactions. Hot dip galvanized steel and stainless steel bolts and nuts are acceptable for connection of aluminum structural plate.

26.3.5—Fabrication

Plates at longitudinal and circumferential seams shall be connected by bolts with the seams staggered so that not more than three plates come together at any one point.

26.3.6—Welding

If required, welding of steel shall conform to the current AASHTO/AWS D1.5M/D1.5 *Bridge Welding Code*. All welding of steel plates, other than fittings, shall be performed prior to galvanizing.

If required, welding of aluminum shall conform to the ANSI/AWS D1.2/D1.2M *Structural Welding Code—Aluminum*.

C26.3.6

Welding references AASHTO/AWS D1.5M/D1.5 *Bridge Welding Code* and ANSI/AWS D1.2/D1.2M *Structural Welding Code—Aluminum*.

26.3.7—Protective Coatings

When required in the contract documents, metal pipes and structural metal plate culverts shall be protected with bituminous coating or have the invert paved with bituminous material. Bituminous coatings shall be applied as provided in AASHTO M 190, Type A, unless otherwise specified in the contract documents. If required, bituminous pavings shall be applied over the bituminous coatings to the inside bottom portion of pipe as provided in AASHTO M 190, Type C, unless otherwise specified in the contract documents. The portion of all nuts and bolts used for assembly of coated structural plate pipe, arches, pipe arches, and box culverts, projecting outside the pipe shall be coated after installation. The portions of the nuts and bolts projecting inside the pipe need not be coated.

When required in contract documents, polymeric coatings shall conform to the requirements of AASHTO M 246 (ASTM A742/A742M). The polymeric coating shall be applied to the galvanized sheet prior to corrugating and, unless otherwise specified in the contract documents, the thickness shall be not less than 0.010 in. Any pinholes, blisters, cracks, or lack of bond shall be cause for rejection. Polymeric coatings are not permitted on structural plate.

26.3.8—Bedding and Backfill Materials

26.3.8.1—General

Bedding shall be loose native or granular material with a maximum particle size less than one-half the corrugation depth. Backfill for metal culverts shall be granular material, as specified in the contract documents and specifications, and shall be free of organic material, rock fragments larger than 3.0 in. in the greatest dimension, and frozen lumps, and shall have a moisture content within the limits required for compaction. As a minimum, backfill materials shall meet the requirements of AASHTO M 145 for A-1, A-2, or A-3.

26.3.8.2—Long-Span Structures

Bedding and backfill materials shall meet the general requirements of Article 26.3.8.1. As a minimum, backfill materials for structures with less than 12.0 ft of cover shall meet the requirements of AASHTO M 145 for A-1, A-2-4, A-2-5, or A-3. Minimum backfill requirements for structures with 12.0 ft or more cover shall meet AASHTO M 145 requirements for A-1 or A-3.

26.3.8.3—Box Culverts

Bedding and backfill materials shall meet the general requirements of Article 26.3.8.1. As a minimum, backfill shall meet the requirements of AASHTO M 145 for A-1, A-2-4, A-2-5, or A-3.

26.3.8.4—Deep Corrugated Structures

For deep corrugated structures, the select backfill within the structural backfill zone shall meet the requirements of AASHTO M 145 A-1, A-2-4, A-2-5, or A-3 (ASTM D2487 classifications GW, GP, SW, SP, GM, SM, SC, GC) and the manufacturer's requirements.

26.4—ASSEMBLY

26.4.1—General

Corrugated metal pipe and structural plate pipe shall be assembled in accordance with the Manufacturer's instructions. All pipe shall be unloaded and handled with reasonable care. Pipe or plates shall not be rolled or dragged over gravel or rock, and shall be prevented from striking rock or other hard objects during placement in the trench or on the bedding.

Corrugated metal pipe shall be placed in the bed starting at the downstream end. Pipes with circumferential seams shall be installed with their inside circumferential sheet laps pointing downstream.

C26.4.1

Bituminous coated pipe, polymer coated pipe, and paved invert pipe shall be installed in a similar manner to corrugated metal pipe with special care in handling to avoid damage to coatings. Paved invert pipe shall be installed with the invert pavement placed and centered on the bottom.

Structural metal plate culverts and pipes shall be assembled and installed as specified in the contract documents and detailed erection instructions. Copies of the Manufacturer's assembly instructions shall be furnished as specified in Article 26.2. Bolted longitudinal seams shall be well fitted with the lapping plates parallel to each other. The applied bolt torque for 0.75-in. diameter (M20) high strength steel bolts (ASTM A449) for the assembly of steel structural plate shall be a minimum of 100 ft · lb and a maximum of 300 ft · lb. Aluminum structural plate shall be assembled using 0.75-in. diameter (M20) aluminum bolts (ASTM F468) or standard strength steel bolts (ASTM A307) which shall be torqued to a minimum of 100 ft · lb and a maximum of 150 ft · lb.

There is no structural requirement for residual torque; the important factor is the seam fit-up.

When seam sealant tape or a shop-applied asphalt coating is used, bolts should be retightened no more than once, and generally within 24 h after initial tightening.

Longitudinal seams in deep corrugated structures shall be staggered.

26.4.2—Joints

Joints for corrugated metal culvert and drainage pipe shall meet the following performance requirements.

26.4.2.1—Field Joints

Transverse field joints shall be of such design that the successive connection of pipe sections form a continuous line free from appreciable irregularities in the flow line. In addition, the joints shall meet the general performance requirements described in Articles 26.4.2.2 through 26.4.2.4.

C26.4.2.1

Suitable transverse field joints, which satisfy the requirements for one or more of the subsequently defined joint performance categories, can be obtained with the following types of connecting bands furnished with the suitable band-end fastening devices:

- Corrugated bands
- Bands with projections
- Flat bands
- Bands of special design that engage factory reformed ends of corrugated pipe
- Other equally effective types of field joints may be used with the approval of the Engineer.

26.4.2.2—Joint Types

The contract document should specify either "Standard" or "Special" joints as appropriate for the requirements at hand.

C26.4.2.2

Standard joints are for pipe not subject to large soil movements or disjointing forces. These joints are satisfactory for ordinary installations where simple slip-type joints are typically used. Special joints are for more severe requirements such as the need to withstand soil movements or resist disjointing forces. Examples of conditions leading to more severe requirements include poor foundation conditions or conditions producing longitudinal hydraulic forces requiring downdrain joints such as pipes on steep slopes or sharp curves.

26.4.2.3—Soil Conditions

Special joints should be specified when poor soil conditions are encountered.

C26.4.2.3

An example of poor soil conditions is when the backfill or foundation material is characterized by large soft spots or voids. If construction in such soil is unavoidable, this condition can only be tolerated for relatively low fill heights, because the pipe must span the soft spots and support imposed loads.

26.4.2.4—Joint Properties

The requirements for joint properties shall be taken as specified in Table 26.4.2.4-1. The values for various types of pipe may be determined by a rational analysis or a suitable test.

The following design issues shall be considered in the design of, or selection of, pipe joints:

- Joint Overlap—Standard joints which do not meet the moment strength alternatively shall have a minimum sleeve width overlapping the abutting pipes. The minimum total sleeve width shall be as given in Table 26.4.2.4-1. Any joint meeting the requirements for a special joint may be used in lieu of a standard joint.

- Soil Tightness—No opening may exceed 1.0 in. In addition, for all categories, if the size of the opening exceeds 0.125 in., the length of the channel shall be at least four times the size of the opening. For nonerodible or erodible soils, the ratio of D_{85} soil size to size of opening must be greater than 0.3 for medium to fine sand or 0.2 for uniform sand; these ratios need not be met for cohesive backfills where the plasticity index exceeds 12 percent. Alternatively, a joint which withstands 2 psi hydrostatic test without leakage shall be considered soil tight. Joints that do not meet these requirements may be made soil tight by wrapping with a suitable geotextile.

C26.4.2.4

The joint resistances in shear and flexure are given in Table 26.4.2.4-1 as a percentage of the respective resistance of a transverse cross-section remote of the joint.

Tensile strength is required in a joint when the possibility exists that a longitudinal load could develop which would tend to separate adjacent pipe sections.

Soil tightness refers to openings in the joint through which soil may infiltrate. Soil tightness is influenced by the size of the opening (maximum dimension normal to the direction that the soil may infiltrate) and the length of the channel (length of the path along which the soil may infiltrate).

As a general guideline, a backfill material containing a high percentage of fine-grained soils requires investigation for the specific type of joint to be used to guard against soil infiltration.

Backfill which is not subject to piping action is classified as "nonerodible." Such backfill typically includes granular soil (with grain sizes equivalent to coarses and, small gravel, or larger) and cohesive soils.

Backfill that is subject to piping action, and would tend to either infiltrate the pipe or to be easily washed by exfiltration of water from the pipe, is classified as "erodible." Such backfill typically includes fine sands and silts.

- Watertightness—The adjoining pipe ends in any joint shall not vary more than 0.5 in. in diameter or more than 1.5 in. in circumference for watertight joints.

Watertightness may be specified for joints of any category where needed to satisfy other criteria. The leakage rate shall be measured with the pipe in place or at an approved test facility. The tolerances indicated may be attained by proper production controls or by match-marking pipe ends.

Table 26.4.2.4-1—Categories of Pipe Joints

	Soil Condition				
	Nonerodible		Erodible		
	Joint Type		Joint Type		
Joint Property	Standard	Special	Standard	Special	Downdrain
Shear Resistance	2%	5%	2%	5%	2%
Moment Resistance	5%	15%	5%	15%	15%
Tensile Resistance 0–42.0 in. dia.	0	5.0 kips	—	5.0 kips	5.0 kips
Tensile Resistance (48.0 in.–84.0 in.), dia.	—	10.0 kips	—	10.0 kips	10.0 kips
Joint Overlap, minimum	10.5 in.	NA	10.5 in.	NA	NA
Soil tightness	NA	NA	0.3 or 0.2	0.3 or 0.2	0.3 or 0.2
Watertightness	See Article C26.4.2.4				

26.4.3—Assembly of Long-Span Structures

Unless held in shape by cables, struts, or backfill, longitudinal seams should be tightened when the plates are hung. Care shall be taken to align plates to ensure properly fitted seams prior to bolt tightening. The variation in structure dimensions before backfill shall comply with the following provisions:

- For horizontal elliptic shapes having a ratio of top to side radii of three or less, the span and rise shall not deviate from the specified dimensions by more than two percent.
- For arch shapes having a ratio of top to side radii of three or more, the rise shall not deviate from the specified dimensions by more than one percent of the span.
- For all other long-span structures, the span and rise shall not deviate from the specified dimensions by more than two percent, nor more than 5.0 in., whichever is less.

When required by structural design, reinforcing ribs shall be attached to the structural plate corrugation crown prior to backfilling, using a bolt spacing of not more than 12.0 in. Legible identifying letters or numbers shall be placed on each rib to designate its proper position in the finished structure.

C26.4.3

Long-span structures may require deviation from the normal practice of loose bolt assembly.

The process of erection specified herein may require temporary shoring.

When required for control of structure shape during installation, reinforcing ribs shall be spaced and attached to the corrugated plates at the discretion of the manufacturer with the approval of the Engineer.

26.5—INSTALLATION

26.5.1—General

For trench conditions, the trench shall be excavated to the width, depth, and grade shown in the contract documents.

Proper preparation of foundation, placement of foundation material where required, and placement of bedding material shall precede the installation of all culvert pipe. This work shall include necessary leveling of the native trench bottom or the top of the foundation material as well as placement and compaction of required bedding material to a uniform grade so that the entire length of pipe will be supported on a uniform base. The backfill material shall be placed and compacted around the pipe in a manner to meet the requirements specified.

Materials used for foundation improvements, bedding and structure backfill must have gradations compatible with adjacent soils to avoid migration. Where material gradations cannot be properly controlled, adjacent materials must be separated with a suitable geotextile.

All pipes shall be protected by sufficient cover before permitting heavy construction equipment to pass over them during construction.

26.5.2—Foundation

The foundation under the pipe and structure backfill shall be investigated for its adequacy to support the loads. A foundation shall be provided, such that the structure backfill does not settle more than the pipe to avoid downdrag loads on the pipe.

The foundation must provide uniform support for the pipe invert. Boulders, rock or soft spots in the foundation shall be excavated to a suitable depth and backfilled with material compacted sufficiently to provide uniform bearing as shown in Figure 26.5.2-1.

C26.5.2

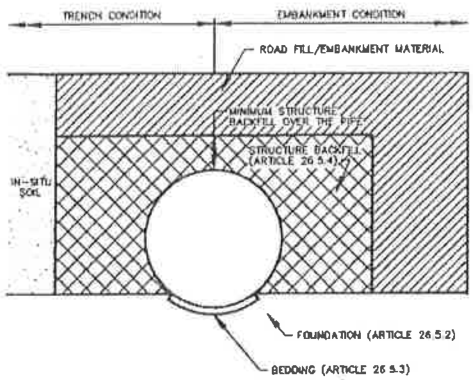
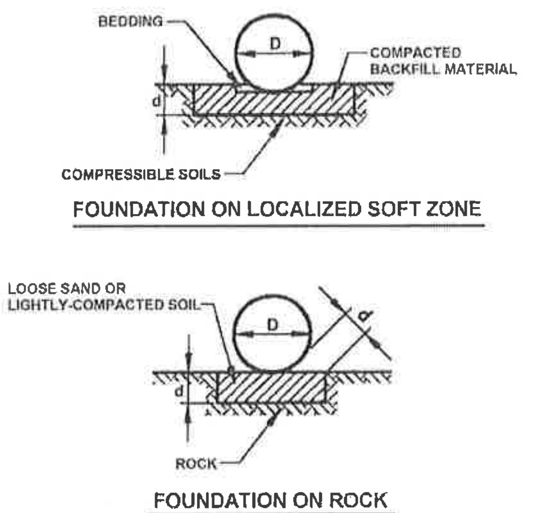


Figure 26.5.2-1—Pipe Installation Nomenclature

Where the natural foundation is judged inadequate by the Engineer to support the pipe or structure backfill, it shall be excavated to a suitable depth and backfilled with material compacted sufficiently to control settlements as shown in Figures 26.5.2-2 and 26.5.2-3.



NOTE:
d =1/2 IN PER FT OF FILL OVER PIPE, WITH A 24 IN MAXIMUM

Figure 26.5.2-2—Foundation Treatment for Localized Soft Spots or Rock

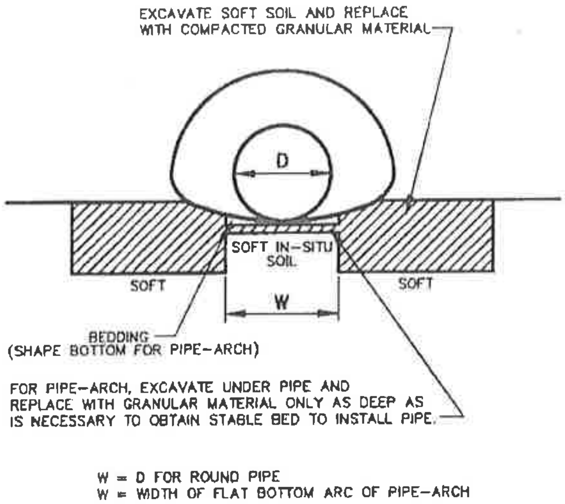


Figure 26.5.2-3—Foundation Treatment for Settlement Control

Where relatively large-radius inverts adjoin small radius corners or sides for sections such as pipe arches, elliptic pipe or underpasses, the foundation shall be designed to support the radial pressures exerted by the smaller radius portions of the pipe. The principal foundation support shall be provided in the area extending radially outward from the smaller radius areas.

These pressures may be two to five times the loading pressures on top of the pipe, depending on the pipe shape.

When corrective measures are necessary, providing less support under the invert allows the pipe to maintain its shape as minor settlements occur as shown in Figure C26.5.2-1.

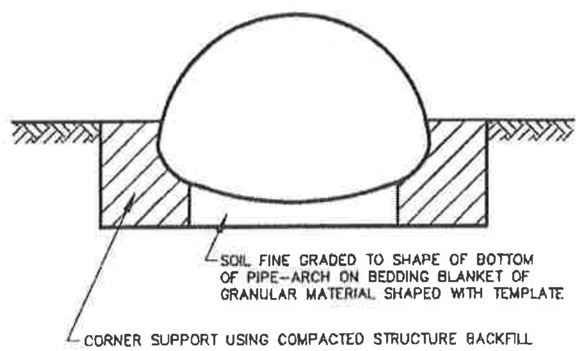


Figure C26.5.2-1—Foundation Treatment for Support of Corner or Side Plate Pressures

Where settlement of the pipe is expected to be so large that the required grade under high fills will not be maintained, pipe may be cambered to prevent excessive sag. The amount of camber shall be determined based on consideration of the flow line, gradient, fill height, the compressive characteristics of the foundation material, and the depth to incompressible strata.

The use of camber under a high fill is shown in Figure C26.5.2-2.

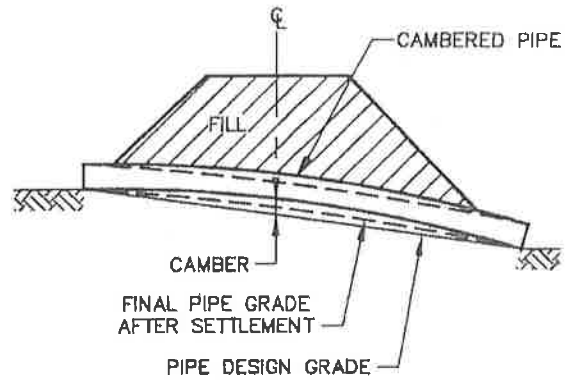


Figure C26.5.2-2—Pipe Camber for Settlement Control under High Fills

26.5.3—Bedding

When, in the opinion of the Engineer, the natural soil does not provide a suitable bed, a bedding blanket shall be provided with a minimum thickness of twice the corrugation depth.

Pipe arch, horizontal elliptic and underpass shapes with spans exceeding 12.0 ft should be placed on a shaped bed. The shaped area should be centered beneath the pipe and should have a minimum width of one-half the span for pipe arch and underpass shapes, and one-third the span for horizontal elliptic shapes. Preshaping may consist of a simple "V" graded into the soil as shown in Figure 26.5.3-1.

C26.5.3

The pipe bedding is a relatively thin layer of loosely-placed material that cushions the pipe invert and allows the corrugation to nest or seat into it, thus supporting the corrugation.

W = SPAN/2 FOR PIPE ARCH AND UNDERPASS
W = SPAN/3 FOR HORIZONTAL ELLIPSE

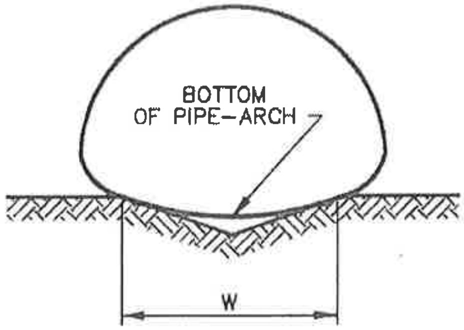


Figure 26.5.3-1—Shaped Bedding for Large Pipe-Arch, Horizontal Ellipse and Underpass Structures

26.5.4—Structure Backfill

26.5.4.1—General

Sufficient inspection and testing should be undertaken to be certain that the quality of the soil and the compactive effort obtained is as specified.

Backfill material shall meet the requirements of Article 26.3.8 and shall be placed in layers not exceeding 8.0-in. loose lift thickness to a minimum 90-percent standard density per AASHTO T 99. Equipment used to compact backfill within 3.0 ft from sides of pipe or from edge of footing for arches and box culverts shall be approved by the Engineer prior to use. Except as provided below for long-span structures, the equipment used for compacting backfill beyond these limits may be the same as used for compacting embankment.

The backfill shall be placed and compacted with care under the haunches of the pipe and shall be raised evenly on both sides of the pipe by working backfill operations from side to side. The side to side backfill differential shall not exceed 24.0 in. or one-third of the rise of the structure, whichever is less. Backfill shall continue to not less than 1.0 ft above the top for the full length of the pipe. Fill above this level shall be embankment fill or other materials as specified to support the pavement. The trench shall be kept to the minimum width required for placing pipe, placing adequate bedding and sidefill, and safe working conditions. Ponding or jetting of backfill shall not be permitted except upon written permission by the Engineer.

Where single or multiple structures are installed at a skew to the embankment, proper support for the pipe shall be provided. Support may be achieved with a rigid, reinforced concrete headwall or by warping the embankment fill to provide the necessary balanced side support. Figure 26.5.4.1-1 provides guidelines for warping the embankment.

C26.5.4.1

Quality control is of extreme importance because the structural integrity of the corrugated metal structure is vitally affected by the quality of construction in the field.

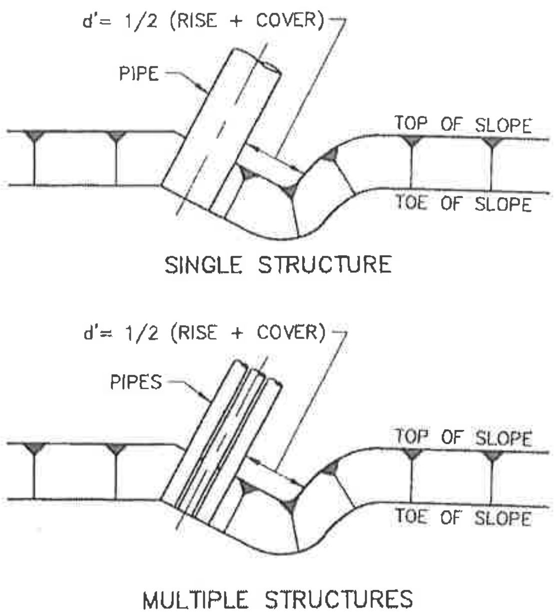


Figure 26.5.4.1-1—End Treatment of Skewed Flexible Culvert

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.

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.

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. 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. 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. 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*.

The ends of the corrugated metal arch shall rest in a keyway formed into continuous concrete footings, or shall rest on a metal bearing surface, usually an angle or channel shape, which is securely anchored to or embedded in the concrete footing.

When specified, the metal bearing may be a hot-rolled or cold-formed galvanized steel angle or channel, or an extruded aluminum angle or channel. These shapes shall be not less than 0.1875 in. in thickness and shall be securely anchored to the footing at a maximum spacing of 24.0 in. When the metal bearing member is not completely embedded in a keyway in the footing, one vertical leg shall be punched to allow the end of the corrugated plates to be bolted to this leg of the bearing member.

Where an invert slab is provided which is not integral with the arch footing, the invert slab shall be continuously reinforced.

26.5.7—Inspection Requirements for CMP

26.5.7.1—Visual Inspection

CMP shall be inspected after placement in the trench, as required during backfilling, and after completion of installation to ensure that final installation conditions allow the pipe to perform as designed. Installation of bedding and backfill materials, as well as their placement and compaction, shall be determined to meet the requirements of this Section.

During the initial phase of the installation process, inspection shall concentrate on detecting improper practice and poor workmanship. Errors in line and grade, as well as any improper assembly or backfill techniques, shall be corrected prior to placing significant backfill or trench fill. Coupling bands shall be properly indexed with the corrugation and tightened, and bell/spigot joints shall be properly seated to prevent the infiltration of soil fines. Where gaskets are used, they shall not bulge or hang into the pipe and, if visible, should appear uniformly oriented around the pipe.

C26.5.7.1

See Article 14.2, "Inspection," of *Highway Drainage Guidelines*.

Inspections at the appropriate times during installation allow corrections to be made in assembly and backfill practices. The timing and number of visual inspections depend on the significance of the structure and its cover depth. Construction inspection during early stages of the project will allow the contractor to evaluate and, if necessary, modify construction and quality control practices.

Deeply buried structures perform closer to their full, allowable strength level. Where the depth of cover will be significant, it is especially important to detect any problems before the pipe is buried to a depth where repair will be difficult or expensive.

Soil consolidation continues with time after installation of the pipe. While 30 days will not encompass the time frame for complete consolidation of the soil surrounding the pipe, it is intended to give sufficient time to

Racking or denting of the pipe shall be taken to indicate improper backfill placement. At the contractor's expense, pipe sections damaged during installation shall be evaluated by a Professional Engineer and when directed, that section of the pipe shall be repaired or replaced.

Coated pipes shall be inspected to ensure the coating has no cracks, scratches, or locations of peeling. Coatings shall be repaired in accordance with material specification requirements.

Final internal inspections shall be conducted on all buried CMP installations to evaluate issues that may affect long-term performance. Final inspections shall be conducted no sooner than 30 days after completion of installation and final fill.

The inspection will verify that bedding, backfill, and compaction requirements are followed during installation. The pipe shall be checked for alignment, joint separation, cracking at bolt holes, localized distortions, bulging, flattening, or racking. Shallow cover installations shall be checked to ensure the minimum cover level is provided and inspected prior to and immediately after vehicular load is applied.

observe some of the effects that this consolidation will have. However, occasionally pavement is placed over the pipe sooner than 30 days. While the 30-day time limit should be maintained, a brief inspection of the pipe prior to paving over it, particularly for the first few joints, may be prudent to ensure that good construction practices are being applied.

It is recommended that inspection personnel not enter culverts less than 24.0 in. in diameter. Internal inspection of culverts in this size range is best conducted using video cameras. Culverts should only be entered by inspection personnel trained in working within confined spaces and using procedures in full compliance with applicable Local, State, and Federal OSHA regulations.

Racking, or loss of symmetry, is structurally important in larger pipes because a flattened area is formed on one side of the crown as the top centerline is racked to the opposite side. Differential shape changes at the joint, or joint separation may allow exfiltration or infiltration resulting in erosion of the backfill material.

Slight peaking of the cross-sectional shape should be taken as indicative of achieving or exceeding minimum compaction requirements.

26.5.7.2—Installation Deflection

The pipe shall be evaluated to determine whether the internal diameter of the barrel has been reduced more than the limits set forth in this Article when measured not less than 30 days following completion of installation.

Because of their broad diameter tolerances, metal pipes 24 in. in diameter and smaller typically are not deflection tested. A visual inspection should be performed to check for denting or other damage using a video camera or other means. If deflection testing is required by the owner or the visual inspection indicates excessive deflection, a device approved by the Engineer that can physically verify the dimensions of the pipe and is not limited by poor lighting, waterflow, pipe length, or other limiting conditions of the installed environment shall be used. If deflection testing is performed, deflection for metal pipes 24 in. in diameter and smaller shall not exceed 7.5 percent of the nominal diameter of the pipe plus a manufacturing tolerance as determined to be appropriate by the owner.

Pipes larger than 24 in. may be entered and deflection levels measured directly. In lieu of direct measurements, a calibrated video camera or any other device approved by the Engineer that can physically verify the dimensions of the pipe and is not limited by poor lighting, waterflow, pipe length, or other limiting conditions of the installed environment may be used.

In all installations of pipes larger than 24 in. in diameter, at least ten percent of the total number of pipe runs representing at least ten percent of the total pipe footage on the project shall be randomly selected by the Engineer and inspected for deflection. Also, as determined by the 100 percent visual inspection in Article 26.5.7.1, all areas in which deflection can be visually detected shall be inspected for deflection.

C26.5.7.2

Ten percent of each pipe installation shall be defined as ten percent of the number of pipe runs, and not less than ten percent of the total length of installed pipe on the project. The requirement of deflection testing ten percent of each pipe installation is intended to serve as a minimum and does not limit owners from more stringent requirements.

There are many appropriate methods for measuring deflection, including video inspection equipment and direct measurement. Whichever method is used for deflection measurement, a minimum of ten percent of the total length of installed pipe shall be tested, in addition to any areas that were identified in the visual inspection as having deflection.

The deflection limits provided are similar to the deflection criteria for other flexible pipes in these Specifications. These limits do not necessarily reflect the capability of the pipe, but were chosen as limits at which the installation indicates poor workmanship that needs to be corrected to prevent future maintenance problems. To prevent owners from having to measure every single pipe to establish base dimensions, deflection measurements shall be based on nominal pipe dimensions. Manufacturing tolerances per AASHTO M 36 for individual products were added to a base deflection limit of 7.5 percent to arrive at the limits as defined in this Article.

Where direct measurements are made, a measurement shall be taken once every 10 ft. for the length of the pipe, and a minimum of four measurements per pipe installation is required.

Pipes larger than 24 in. in diameter should be evaluated by direct measurement. Deflection shall be determined by comparing span and rise measurements with the nominal pipe diameter. Vertical deflection, as a percentage, shall be expressed as: 100((rise/diameter) – 1.0). Similarly, horizontal deflection shall be expressed as: 100((span/diameter) – 1).

For all round pipes larger than 24 in. in diameter, including round and single radius arch structural plate, deflections exceeding 7.5 percent the nominal diameter of the pipe plus the manufacturing tolerance of either one percent of the nominal diameter or 0.5 in., whichever is greater, shall be considered as indicative of poor backfill materials, poor workmanship or both. These pipes shall require remediation or replacement. Passing deflection criterion shall not eliminate the need to evaluate associated denting, racking or other shape damage.

For pipe arches, deflections resulting in a decrease in rise or increase in span exceeding 7.5 percent shall be considered indicative of poor backfill materials, poor workmanship, or both. These pipes shall require remediation or replacement. Passing deflection criterion shall not eliminate the need to evaluate associated denting, racking or other shape damage.

Structural plate structures should be inspected by direct measurement. They shall be assembled in accordance with the shape tolerances of Article 26.4.3. Immediately after backfilling, the structure shall be measured to check for any immediate deflections that occurred during the backfilling operation. After 30 days, the structure shall be measured again to check for any additional deflection. All deflection measurements shall be based on design dimensions. For multiple radius structures such as ellipses, pipe-arches, and low profile and high profile arches, the crown (top) radius shall not increase by more than ten percent of the design radius as calculated from the measured middle ordinate off a suitable length straight edge. If the top radius exceeds the design value by more than ten percent or if the structure is racked or unsymmetrical by more than two percent, it shall require remediation. The degree of racking or loss of symmetry shall be determined by dropping a plumb line from the actual top centerline of the installed structure and measuring the half spans that exist on each side of the plumb line to the maximum span line. For a symmetrical structure, these measurements at each individual cross-section should be equal. The degree of racking or loss of symmetry shall be expressed as a percentage: 100 ((half span A – half span B)/span) < 2.

Due to the broad diameter tolerances on small diameter metal pipes, it is difficult to perform deflection testing as the pass/fail criterion are often inaccurate. However they do need to be checked for denting and other damage. A thorough visual inspection for these pipes is recommended rather than deflection testing. If owners choose to deflection test small diameter pipes, they should keep in mind that the tolerances for round metal pipe are ±1 percent or ±0.5 in., whichever is greater. Manufacturing processes use these tolerances and the diameter often varies within the pipe. Especially in smaller pipes, this is significant to any perceived deflection. A –0.5 in. tolerance in a 12-in. pipe itself amounts to 4.2 percent of the diameter. This manufacturing tolerance, if it is not taken into account, can result in the acceptance of poorly installed pipe or the rejection of well installed pipe. Alternatively, owners who choose to deflection test pipes 24.0 in. and less in diameter can require a manufacturer's certification of the mean diameter, and deflection test based on that data.

According to the tolerance limits established in AASHTO M 36 and AASHTO M 196, the tolerance for the rise in a pipe arch can vary greatly to the positive, but is zero for negative tolerance. Additionally, the tolerance for span in a pipe arch is zero to the positive and can vary greatly to the negative. As such, the threshold criterion for deflection has been set at a 7.5 percent decrease for rise and at a 7.5 percent increase for span. This eliminates the large tolerances for pipe arches as a factor in checking for deflection.

For structural plate structures, a ten percent increase in crown radius does not indicate a ten percent change in rise. Depending on the shape, related rise deflections are more typically five percent or less. Since there are nearly an infinite number of possible design shapes for structural plate, the dimension change limits are compared to base dimensions shown on the working drawings for that particular structure. Measurements should be taken immediately after installation and backfilling, as well as after 30 days, so that corrective measures can be taken if necessary before additional construction over the structure is completed.

26.6—CONSTRUCTION PRECAUTIONS

The structures covered by this section shall be investigated for all critical stages in their installation and in the final intended purpose. For construction loads, additional cover may be required beyond that required in the final condition to which the design loads apply. In the absence of more specific information, the cover depths in Table 26.6-1 may be considered for the smaller structures indicated. The minimum covers indicated should be increased when site conditions so indicate. The Engineer or the Manufacturer shall provide guidance for structure spans or axle loads not listed.

C26.6

These structures can support the design loads once the backfill is placed and compacted to the minimum cover level over the pipe, as defined in Section 12, "Buried Structures and Tunnel Liners," *AASHTO LRFD Bridge Design Specifications*.

Table 26.6-1—Minimum Cover for Construction Loads on Circular, Pipe-Arch, Elliptic, and Underpass Shapes

Pipe Span, in.	Minimum Cover, ft, for Indicated Axle Loads, kips			
	18.0–50.0	50.0–75.0	75.0–110.0	110.0–150.0
12.0–42.0	2.0	2.5	3.0	3.0
48.0–72.0	3.0	3.0	3.5	4.0
78.0–120.0	3.0	3.5	4.0	4.0
126.0–144.0	3.5	4.0	4.5	4.5

The Contractor shall provide any additional cover required to avoid damage to the pipe. Minimum cover shall be measured from the top of the pipe to the top of the maintained construction roadway surface.

The surface shall be maintained to provide adequate cover until paving is completed, or until the project is accepted by the Owner if paving is not required.

26.7—MEASUREMENT

Corrugated metal and structural plate pipe, pipe-arches, arches, and box culverts shall be measured in linear feet installed in place, completed and accepted. The number of linear feet shall be the average of the top and bottom centerline lengths for pipe, the bottom centerline length for pipe arches and box culverts, and the average of springline lengths for arches.

26.8—PAYMENT

Separate pay items or provision for including excavation, backfill, and concrete for arches shall be provided for in the contract documents.

The lengths as measured above shall be paid for at the contract prices per linear foot bid for corrugated metal and structural plate pipe, pipe-arch, arch, or box culvert of the sizes specified in the contract documents. Such price and payment shall constitute full compensation for furnishing, handling, erecting, inspecting shape control, and installing the pipe, pipe-arches, arches, or box culverts, and for all materials, labor, equipment, tools, and incidentals necessary to complete this item. Such price and payment shall also include the cost of excavation, bedding material, backfill, concrete headwalls, endwalls, and foundations for pipe, pipe-arches, and box culverts. Separate payment will be made for excavation, backfill, concrete or masonry headwalls, and foundations for arches.

26.9—REFERENCES

AASHTO. 2007. *AASHTO LRFD Bridge Design Specifications*, Fourth Edition, LRFDUS-4-M or LRFDSI-4. American Association of State Highway and Transportation Officials, Washington, DC.

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AASHTO and AWS. 2008. AASHTO/AWS D1.5M/D1.5:2008 *Bridge Welding Code*, Fifth Edition, BWC-5, American Welding Society, Miami, FL.

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