Designation: C1417 – 15

Standard Specification for Manufacture of Reinforced Concrete Sewer, Storm Drain, and Culvert Pipe for Direct Design[1]

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1. Scope

1.1 This specification covers the manufacture and acceptance of precast concrete pipe designed to conform to the owner's design requirements and to ASCE 15 or an equivalent design specification.

1.2 This specification is the companion to SI Specification C1417M; therefore, no SI equivalents are presented in this specification.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A615/A615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

A706/A706M Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement

A1064/A1064M Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete

C33/C33M Specification for Concrete Aggregates

C76 Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe

C150/C150M Specification for Portland Cement

C260/C260M Specification for Air-Entraining Admixtures for Concrete

C494/C494M Specification for Chemical Admixtures for Concrete

C497 Test Methods for Concrete Pipe, Manhole Sections, or Tile

C595/C595M Specification for Blended Hydraulic Cements

C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C655 Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe

C822 Terminology Relating to Concrete Pipe and Related Products

C989/C989M Specification for Slag Cement for Use in Concrete and Mortars

C1017/C1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete

C1116/C1116M Specification for Fiber-Reinforced Concrete

C1602/C1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

2.2 *Other Standards:*

ASCE 15 Standard Practice for the Direct Design of Buried Precast Reinforced Concrete Pipe Using Standard Installations (SIDD)[3]

ACI 318 Building Code Requirements for Reinforced Concrete[4]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms relating to concrete pipe, see Terminology C822.

3.1.2 *group of pipe sections, n*—each day's production run of pipe sections of a single concrete strength for a specific project.

3.1.3 *lot of pipe sections, n*—total of the number of groups of pipe sections of a single concrete strength produced for a specific project.

3.1.4 *running average, n*—average concrete compressive strength of all groups of pipe sections of a single concrete strength produced for a specific project, generally determined as each group is tested.

4. Basis of Acceptance of Design

4.1 *Manufacturing Design Data*—The manufacturer shall submit the following manufacturing design data for the concrete pipe to the owner for approval.

4.1.1 Pipe wall thickness.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191, http://www.asce.org.

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

4.1.2 Concrete strength.
4.1.3 *Reinforcement:*
4.1.3.1 Specification,
4.1.3.2 Reinforcement Type 1, 2, or 3, where:

Type 1: Smooth wire or plain bars
Type 2: Welded smooth wire reinforcement, 8 in. maximum spacing of longitudinals
Type 3: Welded deformed wire reinforcement, deformed wire, deformed bars, or any reinforcement with stirrups, anchored thereto

4.1.3.3 Design yield strength,
4.1.3.4 Placement and design concrete cover,
4.1.3.5 Cross-sectional diameters,
4.1.3.6 Spacing,
4.1.3.7 Cross-sectional area,
4.1.3.8 Description of longitudinal members, and
4.1.3.9 If stirrups are used, developable stirrup design stress, stirrup shape, placement, and anchorage details.
4.1.4 Design factors and the assumed orientation angle.
4.1.5 Pipe laying length and joint information.

4.2 Approval of the manufacturing design data shall be based on its conformance to the owner's design requirements and to ASCE 15 or to an equivalent design specification.

5. Basis of Acceptance of Concrete Pipe

5.1 Acceptance of pipe shall be on the basis of concrete compression tests, materials tests, conformance to the manufacturing design data, conformance to this specification, and inspection of manufactured pipe for defects.

5.2 When mutually agreed in writing by the owner and the manufacturer, a certification may be made the basis of acceptance of the concrete pipe. This certification shall consist of a statement by the manufacturer that the concrete pipe conforms to the manufacturing design data and to this specification, and that the concrete and materials have been sampled and tested and conform to this specification.

5.3 *Age for Acceptance*—Pipe shall be considered ready for acceptance when they conform to the requirements of this specification.

6. Material

6.1 *Reinforced Concrete*—The reinforced concrete shall consist of cementitious materials; mineral aggregates; admixtures, if used; and water in which steel has been embedded in such a manner that the steel and concrete act together.

6.2 *Cementitious Material:*
6.2.1 *Cement*—Cement shall conform to the requirements for portland cement of Specification C150/C150M or shall be portland blast-furnace slag cement, portland-limestone cement, or portland-pozzolan cement conforming to the requirements of Specification C595/C595M, except that the pozzolan constituent in the Type IP portland-pozzolan cement shall be fly ash.
6.2.2 *Slag Cement*—Slag cement shall conform to the requirements of Grade 100 or 120 of Specification C989/C989M.
6.2.3 *Fly Ash*—Fly ash shall conform to the requirements of Specification C618, Class F or Class C.
6.2.4 *Allowable Combinations of Cementitious Materials*—The combination of cementitious materials used in the concrete shall be one of the following:
6.2.4.1 Portland cement only.
6.2.4.2 Portland blast-furnace slag cement only.
6.2.4.3 Portland-pozzolan cement only.
6.2.4.4 Portland-limestone cement only,
6.2.4.5 A combination of portland cement or portland-limestone cement and slag cement.
6.2.4.6 A combination of portland cement or portland-limestone cement and fly ash, or
6.2.4.7 A combination of portland cement or portland-limestone cement, slag cement, and fly ash, or
6.2.4.8 A combination of portland-pozzolan cement and fly ash.

6.3 *Aggregates*—Aggregates shall conform to the requirements of Specification C33/C33M, except that the requirement for gradation shall not apply.

6.4 *Admixtures*—The following admixtures and blends are allowable:
6.4.1 Air-entraining admixture conforming to Specification C260/C260M;
6.4.2 Chemical admixture conforming to Specification C494/C494M;
6.4.3 Chemical admixture for use in producing flowing concrete conforming to Specification C1017/C1017M; and
6.4.4 Chemical admixture or blend approved by the owner.

6.5 *Steel Reinforcement*—Reinforcement shall consist of wire and welded wire conforming to Specification A1064/A1064M; or of bars conforming to Specifications A615/A615M, Grade 40 or 60, or A706/A706M, Grade 60. For helically wound cages only, weld shear tests are not required.

6.6 *Water*—Water used in the production of concrete shall be potable or non-potable water that meets the requirements of Specification C1602/C1602M.

6.7 *Fibers*—Synthetic fibers and nonsynthetic fibers shall be allowed to be used, at the manufacturer's option, in concrete pipe as a nonstructural manufacturing material. Synthetic fibers (Type II and Type III) and nonsynthetic fiber (Type I) designed and manufactured specifically for use in concrete and conforming to the requirements of Specification C1116/C1116M shall be accepted.

7. Joints

7.1 The joints shall be designed and the ends of the concrete pipe sections shall be formed so that the sections can be laid together to make a continuous line of pipe, compatible with the permissible variations given in Section 15.

8. Manufacture

8.1 *Mixture*—The aggregates shall be sized, graded, proportioned, and mixed with such proportions of cementitious material, water, and admixtures, if any, to produce a thoroughly mixed concrete of such quality that the pipe will conform to the test and design requirements of this specification. All concrete shall have a water-cementitious materials ratio not exceeding 0.53 by weight. Minimum concrete strength shall be 4000 psi.

8.2 *Finish*—Pipe shall be substantially free of fractures, large or deep cracks, and surface roughness. The ends of the pipe shall be normal to walls and center line of the pipe, within the limits of variations given in Section 15.

9. Circumferential Reinforcement

9.1 A line of circumferential reinforcement for any given total area may be composed of up to two layers for pipe with wall thicknesses of less than 7 in. or three layers for pipe with wall thickness of 7 in. or greater. The layers shall not be separated by more than the thickness of one longitudinal plus ¼ in. The multiple layers shall be fastened together to form a single cage. If the multiple layers of a cage contain circumferential splices, the individual layers shall be rotated so that the splices are staggered. All other specification requirements, such as laps, welds, tolerances of placement in the wall of the pipe, and so forth, shall apply to this method of fabricating a line of reinforcement. The design shall be based on the centroid of the layers.

9.2 Reinforcement placement and concrete cover shall conform to the approved manufacturing data. The nominal concrete cover over the circumferential reinforcement shall not be less than 1 in. in pipe having a wall thickness of 2½ in. or greater, and shall not be less than ¾ in. in pipe having a wall thickness of less than 2½ in. The location of the reinforcement shall be subject to the permissible variations in dimensions given in Section 15. Requirements for placement and protective covering of the concrete from the inner or outer surface of the pipe do not apply to that portion of a cage that is flared so as to extend into the bell or reduced in diameter so as to extend into the spigot.

9.3 Where the wall reinforcement does not extend into the joint area, the maximum longitudinal distance to the last circumferential from the inside shoulder of the bell or the shoulder of the spigot shall be 3 in., except that if this distance exceeds one half of the wall thickness, the pipe wall shall contain at least a total reinforcement area of the minimum specified area per linear foot times the laying length of the pipe section. The minimum cover on the last circumferential near the spigot shoulder shall be ½ in.

9.4 Where reinforcement is in the bell or spigot, the minimum end-cover on the last circumferential shall be ½ in. in the bell or ¼ in. in the spigot.

9.5 The continuity of the circumferential reinforcing steel shall be maintained during the manufacture of the pipe, except when, as agreed upon by the owner, lift eyes or holes are provided in each pipe or the pipe is converted into a manhole tee.

10. Welds, Splices, and Development of Circumferential Reinforcement

10.1 *General:*

10.1.1 When pipe are not marked to show a specific orientation in the ground, any weld to, or splice of, a circumferential shall be considered to be at the point of the maximum flexural stress.

10.1.2 When pipe are marked to show a specific orientation in the ground, any weld to, or splice of, a circumferential shall be considered to be at a distance determined by the orientation angle closer to the point of maximum flexural stress than the marking indicates.

10.1.3 Splices of smooth and deformed wire shall be welded and shall meet the requirements of 10.3 and 10.4.

10.2 *Notation:*

A_{wa} = actual steel area of the individual circumferential wire, in.^{2}
A_{wr} = steel area required for the individual circumferential wire for flexure, in.^{2}, either at the splice, for splices, or at the point of maximum moment, for quadrant mat reinforcement.
d_b = diameter of reinforcing wire or bar, in.
f'_c = design compressive strength of concrete, lb/in.^{2}.
f_y = design yield strength of reinforcement, lb/in.^{2}.
L_d = development length of reinforcing wire or bar, in.
s = spacing of wire to be developed or spliced, in.

10.3 *Welds:*

10.3.1 When splices are welded there shall be a minimum lap of 2 in. and a weld of sufficient length such that pull test of representative specimens shall develop at least 50 % of the minimum specified tensile strength of the steel. For butt-welded splices in bars or wire, permitted only with helically wound cages, pull tests of representative specimens shall develop at least 75 % of the minimum specified tensile strength of the steel.

10.4 *Lapped Splices of Circumferential Reinforcement:*

10.4.1 If lapped splices of circumferentials consisting of deformed bars #6 or less are not welded, they shall be lapped not less than L_d, where:

$$L_d = \frac{d_b f_y A_{wr}}{33\sqrt{f'_c}\, A_{wa}} \quad (1)$$

or not less than:

$$\frac{d_b f_y}{66\sqrt{f'_c}} \quad (2)$$

whichever is greater. Splices of larger than #6 bars shall meet the requirements of ACI 318.

10.4.2 If lapped splices of circumferentials consisting of welded smooth wire reinforcement or welded deformed wire reinforcement are not welded, the overlap measured between the outermost longitudinals on each side of the splice shall be no less than the spacing of the longitudinals plus 1 in. or L_d, where:

$$L_d = 0.27\frac{A_{wr} f_y}{s\sqrt{f'_c}} \quad (3)$$

whichever is greater.

10.4.3 At the option of the manufacturer, a more detailed analysis may be made and the following exception to the requirements of 10.4.2 may be applied. If the area of circumferential reinforcement is at least twice that required for flexure, the first requirement of 10.4.2 shall not apply. The overlap measured between the outermost longitudinals on each side of the splice shall be no less than that required by Eq 3, or 1 in., whichever is greater.

10.4.4 Alternative splice designs that differ from 10.4 may be submitted to the owner for approval.

10.5 *Development of Quadrant Mat Reinforcement:*

10.5.1 Circumferential quadrant mat reinforcement shall consist of welded wire reinforcement with 8-in. maximum cross wire spacing. When quadrant mat reinforcement is used, the area of the main cage shall be no less than 25 % of the area required at the point of maximum moment. The quadrant mats shall extend at least 45° on each side of the point of maximum moment.

10.5.2 At the option of the manufacturer, a more detailed analysis may be made and the requirements of 10.5.3 or 10.5.4 used instead of 10.5.1.

10.5.3 When circumferential quadrant mat reinforcement consists of welded smooth wire reinforcement or welded deformed wire reinforcement, the following requirements shall apply:

10.5.3.1 The outermost longitudinals on each end of the circumferentials shall be embedded in accordance with the following requirements: *(1)* past the point where the quadrant reinforcement is no longer required by the orientation angle plus the greater of twelve circumferential wire diameters or three quarters of the wall thickness of the pipe, and *(2)* past the point of maximum flexural stress by the orientation angle plus the development length, L_d, required by Eq 3.

10.5.3.2 The mat shall contain no less than two longitudinals at a distance 1 in. greater than that determined by the orientation angle from either side of the point requiring the maximum flexural reinforcement.

10.5.3.3 The point of embedment of the outermost longitudinals of the mat shall be at least a distance determined by the orientation angle past the point where the continuing reinforcement is no less than double the area required for flexure.

10.5.4 When circumferential quadrant mat reinforcement consists of #6 or less deformed bars, the following requirements shall apply:

10.5.4.1 Circumferentials shall extend past the point where they are no longer required by the orientation angle plus the greater of twelve wire diameters or three quarters of the wall thickness of the pipe.

10.5.4.2 Circumferentials shall extend either side of the point of maximum flexural stress not less than the orientation angle plus the development length, L_d, required by Eq 1.

10.5.4.3 Circumferentials shall extend at least a distance determined by the orientation angle past the point where the continuing reinforcement is no less than double the area required for flexure.

10.5.4.4 Development of larger than #6 bars shall meet the requirements of ACI 318.

11. Stirrup Reinforcement

11.1 The number of lines of stirrups shall be sufficient to include the distance determined by calculation where V_u is less than V_c plus the distance l_θ as determined in Section 12.6.4.1 of ASCE 15 or as determined by the requirements of an equivalent design specification. The required number of lines of stirrups shall be equally distributed on each side of the point of maximum moment.

11.2 Stirrups used to resist radial tension shall be anchored around each circumferential of the inside cage.

11.3 When stirrups are not required for radial tension but required for shear, their longitudinal spacing shall be such that they are anchored either at every or every other inside face tension circumferential. Such spacing shall not exceed 6 in.

11.4 Stirrups intended to resist forces in the invert and crown regions shall be anchored around the inside circumferentials and anchored sufficiently in the concrete compression zone on the opposite side of the pipe wall to develop the design strength of the stirrup.

11.5 Anchorage of both ends of the stirrup shall be sufficient to develop the factored stress in the stirrup. The maximum factored tensile stress in the stirrup shall be the yield stress or the stress that can be developed by anchorage, whichever is less.

12. Longitudinal Reinforcement

12.1 Circumferential reinforcement shall be assembled into a cage containing sufficient longitudinal members to maintain the circumferential reinforcement in correct position within the pipe.

13. Joint Reinforcement

13.1 *General*—The length of the joint as used in this specification means the inside length of the bell or the outside length of the spigot from the shoulder to the end of the pipe section. The end distances or cover on the end circumferential shall apply to any point on the circumference of the pipe or joint. When convoluted reinforcement is used, these distances and reinforcement areas shall be taken from the points on the convolutions closest to the end of the pipe section. The following requirements for joint reinforcement shall apply.

13.2 *Non-Rubber Gasket Joints:*

13.2.1 For pipe less than 36 in. in diameter, neither the bell or spigot require circumferential reinforcement.

13.2.2 For pipe 36 in. and larger in diameter, either the bell or spigot shall contain circumferential reinforcement. This reinforcement shall be an extension of a wall cage or may be a separate cage of at least the area per linear foot of that specified for the outer cage or one half of that specified for single cage wall reinforcement, whichever is less.

13.2.3 Where bells or spigots require reinforcement, the maximum end cover on the last circumferential shall be one-half the length of the joint or 3 in., whichever is less.

13.3 *Rubber Gasket Joints:*

13.3.1 For pipe 12 in. and larger in diameter, the bell ends shall contain circumferential reinforcement. This reinforcement shall be an extension of the outer cage or a single wall cage, whichever is less, or it may be a separate cage of at least the same area per linear foot with longitudinals as required in Section 12. If a separate cage is used, the cage shall extend into the pipe with the last circumferential wire at least 1 in. past the inside shoulder where the pipe barrel meets the bell of the joint.

13.3.2 When bells require reinforcement, the maximum end cover on the last circumferential shall be 1½ in.

14. Physical Requirements

14.1 *Concrete Compressive Strength Testing, Type of Specimen*—Compression tests for determining concrete compressive strength may be made on either concrete cylinders or on cores drilled from the pipe.

14.2 *Acceptance by Cylinder Tests:*

14.2.1 Cylinders shall be prepared in accordance with Section 11 of Test Methods C497.

14.2.2 *Number of Cylinders*—Prepare not less than five test cylinders from a group (one day's production) of pipe sections.

14.2.3 *Evaluation of Test Results:*

14.2.3.1 When the compressive strengths of all cylinders tested for a group are equal to or greater than the design concrete strength, the compressive strength of concrete in the group of pipe sections shall be acceptable.

14.2.3.2 When the running average compressive strength of all cylinders tested in a lot is equal to or greater than the design concrete strength, not more than 10 % of the cylinders tested have a compressive strength less than the design concrete strength, and no cylinder tested has a compressive strength less than 80 % of the design concrete strength, then the compressive strength of the concrete in the lot of pipe sections shall be acceptable.

14.2.3.3 If the concrete strength for a group does not meet the required concrete strength because of faulty cylinders or faulty production, the manufacturer may cull that group from the lot and running average. A group culled because of faulty cylinders may be accepted in accordance with the provisions of 14.2.3.4.

14.2.3.4 When the concrete compressive strength of the cylinders tested for a group or for a lot does not conform to the acceptance criteria in 14.2.3.1 or 14.2.3.2, the acceptability of the group or lot shall be determined by additional tests on cores in accordance with the provisions of 14.3.

14.3 *Acceptance by Core Tests:*

14.3.1 *Obtaining Cores*—Core specimens shall be obtained, prepared, and tested in accordance with Test Methods C497.

14.3.2 *Number of Cores*—Three cores shall be taken from three sections (one core from each) selected at random from each group of pipe sections or fraction thereof of a single size from each continuous production run.

14.3.3 *Evaluation of Test Results:*

14.3.3.1 Concrete represented by these three core tests shall be considered acceptable if the average of the three core strengths is equal to or greater than 85 % of the required compressive strength and no single core is less than 75 % of the required compressive strength.

14.3.3.2 If the compressive strength of the three cores does not meet the requirements of 14.3.3.1, the sections from which the cores were taken shall be rejected. Two pipe sections from the remainder of the group shall be selected at random, and one core shall be taken from each and tested. If both cores have a strength equal to or greater than 85 % of the required strength, the remainder of the group is acceptable. If the compressive strength of either of the two cores is less than 85 % of the required strength, the remainder of the group shall be rejected or, at the option of the manufacturer, each pipe section of the remaining group shall be cored and accepted individually, and any of these pipe sections that have core strengths less than 85 % of the required strength shall be rejected.

14.3.4 *Plugging Core Holes*—Core holes shall be plugged and sealed by the manufacturer in a manner such that the pipe section will meet all the requirements of the specification. Pipe sections so plugged and sealed shall be considered acceptable for use.

15. Permissible Variations

15.1 *Pipe Diameter*—The internal diameter of 12 to 24 in. pipe shall vary not more than ±1.5 % from the design diameter. The internal diameter of 27 to 144 in. pipe shall vary not more than ±1 % or ±3⁄8 in., whichever is greater, from the design diameter.

15.2 *Reinforcement Area*—Reinforcement will be considered as meeting the design requirements if the area, computed on the basis of nominal area of the wire or bars used, equals or exceeds the design requirements. Actual area of the reinforcement used may vary from the nominal area in accordance with permissible variations of the standard specifications for the reinforcement.

15.3 *Reinforcement Placement*—The maximum variation in the nominal location of the reinforcement shall be ±10 % of the wall thickness. In no case, however, shall the cover over the circumferential reinforcement be less than 5⁄8 in.

15.4 *Length of Two Opposite Sides*—Variations in the laying length of two opposite sides of pipe shall not be more than ¼ in. for all sizes through 24-in. internal diameter, and not more than 1⁄8 in./ft of internal diameter for all larger sizes, with a maximum of 5⁄8 in. in any pipe through 84-in. internal diameter, and a maximum of ¾ in. for 90-in. internal diameter, or larger, except where beveled-end pipe for laying on curves is specified by the owner.

15.5 *Length of Pipe*—The underrun in length of a section of pipe shall not be more than 1⁄8 in./ft with a maximum of ½ in. in any length of pipe.

15.6 *Wall Thickness*—The wall thickness shall be not less than the nominal specified in the design by more than 5 % or 3⁄16 in., whichever is greater. A wall thickness more than that required in the design is not cause for rejection.

16. Inspection

16.1 The quality of materials, process of manufacture, and the finished pipe shall be subject to inspection by the owner.

16.2 *Rejection:*

16.2.1 Pipe shall be subject to rejection for failure to conform to any of the requirements of this specification. Individual sections of pipe may be rejected because of any of the following:

16.2.1.1 Fractures or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint.

16.2.1.2 Defects that indicate proportioning, mixing and molding not in compliance with 6.1, or surface defects indicating honeycombed or open texture that would adversely affect the function of the pipe.

16.2.1.3 Damaged ends when such damage would prevent making a satisfactory joint.

16.2.1.4 Any continuous crack having a surface width of 0.01 in. or more and extending for a length of 1 ft or more, regardless of position in the wall of the pipe.

16.2.1.5 The ends of the pipe are not normal to the walls and centerline of the pipe, within the limits of variations given in 15.4 and 15.5.

16.2.2 The exposure of ends of longitudinals, stirrups, or spacers that have been used to position the cages during the placement of the concrete is not cause for rejection.

16.3 *Repairs*—Pipe may be repaired, if necessary, because of imperfections in manufacture or damage during handling or if it has been cored for testing, and it will be acceptable if the repairs are sound and the repaired pipe conforms to the requirements of this specification.

17. Marking

17.1 The following information shall be legibly marked on each pipe section with waterproof paint or indented:

17.1.1 The pipe designation shall be indicated as follows:

D_i_____T_____H_____-_____

where:

D_i = designated pipe internal diameter, in.,
T = installation type, and
H = minimum—maximum fill height, ft.

17.1.2 Date of manufacture.

17.1.3 Name or trademark of the manufacturer.

17.1.4 Plant identification.

17.1.5 One end of each section of pipe reinforced with elliptical cages, quadrant mats, or stirrups and designed to be installed with a particular axis of orientation shall be legibly marked during the process of manufacturing, or immediately thereafter, on the inside crown and outside top of pipe or shall have the orientation identified by the location of one or more lift holes.

18. Keywords

18.1 concrete pipe; reinforced; culvert; sewer pipe; storm drain; direct design

APPENDIX

(Nonmandatory Information)

X1. EXPLANATORY INFORMATION

X1.1 *Scope (see Section 1)*—The concrete pipe manufacturing requirements in this standard are similar to the requirements given in Specifications C76 and C655. The requirements are modified to be compatible with ASCE 15, which specifies direct design procedures for buried concrete pipe instead of indirect procedures based on the three-edge bearing test. This specification contains manufacturing requirements, detailing requirements for reinforcement, acceptance of design, and acceptance of concrete pipe based on materials tests and visual inspection.

X1.2 Acceptance of Concrete Pipe

X1.2.1 This specification has been developed as the manufacturing standard for pipe designed and installed in accordance with ASCE 15. Pipe designs and specifying of pipe in accordance with ASCE 15 is in terms of pipe reinforcement required for a height of earth cover for a pipe installed in a specific Standard installation. Consequently, the three-edge bearing test and D-load strength are not applicable.

X1.2.2 Critical items for strength characteristics are wall thickness, concrete strength, and reinforcement type, placement and area. Inspection for strength characteristics can be made by observations and measurements during manufacture or tests, or both, and observations and measurements of cores taken from randomly selected pipe sections.

X1.3 Welds, Splices, and Development of Circumferential Reinforcement

X1.3.1 *General (see 10.1)*—Weld and splice strength requirements are based on the assumption that the weld or splice will occur at the location of maximum flexural stress. When the pipe is to be installed with a specific orientation that is marked on the pipe, the manufacturer may elect to determine the factored stress at a splice location and design the splice for that stress. The assumed stress at the splice location must account for misplacement (rotation) of the pipe during installation of at least the orientation angle in the direction of increasing stress.

X1.3.2 *Welds (see 10.3)*—Improper welding procedures can damage circumferential wires or not develop adequate strength. The manufacturer will perform pull tests on representative specimens of circumferentials with welds to substantiate the adequacy of the circumferentials after welding.

X1.3.3 Tests on welded lapped splices embedded in concrete show that the strength of the wire is more important than the strength of the weld. Overheating of the wire while welding may help make a strong weld but it also tends to weaken the wire. The effect of bond is also important to the strength of the embedded splice. The results of pull tests on splices not embedded in concrete do not reflect these factors. The embedded weld factor corrects for the embedded strength of a welded lapped splice measured in a non-embedded condition.

X1.3.4 The minimum overlap lengths for lapped splices that are not welded is based on ACI 318 with modifications appropriate for reinforced concrete pipe (see 10.4.1 – 10.4.3).

X1.3.5 *Development of Quadrant Mat Reinforcement:*

X1.3.5.1 Design studies have demonstrated that if the area of welded wire reinforcement quadrant mat reinforcing does not exceed 75 % of the total required reinforcement at the point of maximum moment, no special analysis for the location of mat cut off points need be performed if the mat reinforcement extends at least 45° beyond each side of the point of maximum moment. No additional extension for orientation angle is required if the specified orientation angle is equal to or less than 10° (see 10.5.1).

X1.3.5.2 The requirements for determining cut off points for mat reinforcement that are given in these sections are based on criteria given in ACI 318. They are to be used when a detailed analysis of mat reinforcement cutoff points is performed by the manufacturer (see 10.5.2 – 10.5.4).

X1.4 *Stirrup Reinforcement (see Section 11)*—To be effective, stirrups must have sufficient anchorage at each end to develop their design tensile strength. At the inside of the pipe wall, stirrups should be anchored around the inside circumferential reinforcement. This gives positive anchorage to resist any radial tension stresses. Because of fabrication requirements of concrete pipe, it is usually not practical to anchor the outside end of stirrups to the outside circumferential reinforcement. Several proprietary stirrup configurations have been developed and tested for adequate anchorage, both in the tension zone of the pipe wall on the inside of the pipe and in the opposite side or compression side near the outside of the pipe.

X1.5 *Longitudinal Reinforcement (see Section 12)*—Except for special cases, such as where pipe is supported on piers, there are no specific requirements for a minimum amount of longitudinal reinforcement. Long-standing successful practice in the concrete pipe industry has shown that this is practical due to the limited length of typical precast concrete pipe sections.

X1.6 *Joint Reinforcement (see Section 13)*—Requirements for joint reinforcement are the same as Specification C76.

X1.7 *Core Tests (see Section 14)*—The percentages shown for acceptance are in accordance with the ACI Code which states, "To expect core tests to be equal to fc is not realistic, since differences in the size of specimens, conditions of obtaining samples, and procedures for curing, do not permit equal values to be obtained." The variations of the specimens such as the length to diameter ratio, drilling direction and process, aggregate size and sample preparation may all have an effect on the test results. Embedded steel reinforcement affects the test results because of the loss of concrete continuity.