Designation: C1417M – 13

Standard Specification for Manufacture of Reinforced Concrete Sewer, Storm Drain, and Culvert Pipe for Direct Design (Metric)[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 the ASCE 15 or an equivalent design specification.

NOTE 1—The section on evaluation of core test results (14.3.3) and the Appendix are currently being reballoted.

1.2 This specification is the SI companion to Specification C1417.

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 Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement

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

C33 Specification for Concrete Aggregates

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

C150 Specification for Portland Cement

C260 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 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 Specification for Slag Cement for Use in Concrete and Mortars

C1017/C1017M Specification for Chemical Admixtures for Use in Producing Flowing 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*—each day's production run of pipe sections of a single concrete strength for a specific project.

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

3.1.4 *running average*—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.

4.1.2 Concrete strength.

4.1.3 *Reinforcement:*

4.1.3.1 Specification,

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[1] This specification is under the jurisdiction of ASTM Committee C13 on Concrete Pipe and is the direct responsibility of Subcommittee C13.05 on Special Projects.

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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.

4.1.3.2 Reinforcement Type 1, 2, or 3, where:

Type 1:	Smooth wire or plain bars
Type 2:	Welded smooth wire reinforcement, 200 mm 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 or shall be portland blast-furnace slag cement or portland-pozzolan cement conforming to the requirements of Specification C595, 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.

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 A combination of portland cement and slag cement.

6.2.4.5 A combination of portland cement and fly ash, or

6.2.4.6 A combination of portland cement, slag cement (not to exceed 25 % of the total cementitious weight), and fly ash (not to exceed 25 % of the total cementitious weight).

6.3 *Aggregates*—Aggregates shall conform to the requirements of Specification C33, 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;

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 280 MPa or 420 MPa, or A706/A706M, Grade 420 MPa.

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 *Concrete*—The aggregates shall be sized, graded, proportioned, and mixed with cementitious material and water and admixtures, if any, to produce a thoroughly mixed concrete of such quality that the pipe will conform to the design requirements of this specification. The water-cementitious material ratio of all concrete shall be 0.53, or less, by weight. Minimum concrete strength shall be 27.6 MPa.

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 180 mm or three layers for pipe with wall thickness of 180 mm or greater. The layers shall not be separated by more than the thickness of one longitudinal plus 6 mm. 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 be 25 mm in pipe having a wall thickness of 63 mm or greater, and shall not be less than 19 mm in pipe having a wall thickness of less than 63 mm. 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 75 mm, 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 metre times the laying length of the pipe section. The minimum cover on the last circumferential near the spigot shoulder shall be 13 mm.

9.4 Where reinforcement is in the bell or spigot, the minimum end-cover on the last circumferential shall be 13 mm in the bell or 6 mm 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, mm^2.
A_{wr} = steel area required for the individual circumferential wire for flexure, mm^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, mm.
f'_c = design compressive strength of concrete, MPa.
f_y = design yield strength of reinforcement, MPa.
F_w = embedded weld factor (see 10.4.3).
L_d = development length of reinforcing wire or bar, mm.
P_t = pull test strength of wire or bar at break, N.
s = spacing of wire to be developed or spliced, mm.

10.3 *Welds:*

10.3.1 For butt splices of circumferentials or where welds are made to circumferentials, pull tests of representative specimens of the circumferential across the finished weld shall demonstrate a strength of no less than 1.1 times the design yield strength of the circumferential except as provided in 10.4.

10.3.2 At the option of the manufacturer, a more detailed analysis may be made and the requirements of this section used instead of 10.3.1. For butt splices of circumferentials or where welds are made to circumferentials, pull tests, P_t, of representative specimens of the circumferential across the finished weld shall demonstrate a strength of no less than:

$$P_t = 1.1 A_{wr} f_y \quad (1)$$

or no less than:

$$P_t = 0.5 A_{wa} f_y \quad (2)$$

whichever is greater.

10.4 *Lapped Splices of Circumferential Reinforcement:*

10.4.1 Where lapped circumferentials are spliced by welding, they shall be lapped no less than 50 mm. Pull tests of representative specimens shall develop no less than 0.9 times design yield strength of the circumferential.

10.4.2 At the option of the manufacturer, a more detailed analysis may be made and the requirements of 10.4.2 and 10.4.3 used instead of 10.4.1. Where lapped circumferentials are spliced by welding, they shall be lapped no less than 50 mm. Pull tests, P_t, of representative specimens shall develop no less than:

$$P_t = F_w A_{wr} f_y \quad (3)$$

or not less than the strength required by Eq 2, whichever is the greater.

10.4.3 The embedded weld factor, F_w, relates the pull test strength of the non-embedded splice specimens to the strength of the splice embedded in the concrete of the pipe wall.

10.4.3.1 If the pull test break is in the wire, F_w shall be taken as 0.90.

10.4.3.2 If the pull test break is in the weld, F_w shall be taken as 0.70.

10.4.4 If lapped splices of circumferentials consisting of deformed bars #19 or less are not welded, they shall be lapped not less than L_d, where:

$$L_d = \frac{d_b f_y A_{wr}}{2.74 \sqrt{f'_c} A_{wa}} \quad (4)$$

or not less than:

$$d_b = \frac{f_y}{5.48 \sqrt{f'_c}} \quad (5)$$

whichever is greater. Splices of larger than #19 bars shall meet the requirements of ACI 318.

10.4.5 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 25 mm, or L_d, where:

$$L_d = 3.25 \frac{A_{wr} f_y}{s \sqrt{f'_c}} \tag{6}$$

whichever is greater.

10.4.6 At the option of the manufacturer, a more detailed analysis may be made and the following exception to the requirements of 10.4.5 may be applied. If the area of circumferential reinforcement is at least twice that required for flexure, the first requirement of 10.4.5 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 6, or 25 mm, whichever is greater.

10.4.7 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 200-mm 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° 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 6.

10.5.3.2 The mat shall contain no less than two longitudinals at a distance 25 mm 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 #19 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 4.

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 #19 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_0 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 150 mm.

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 900 mm in diameter, neither the bell or spigot require circumferential reinforcement.

13.2.2 For pipe 900 mm and larger in diameter, either the bell or spigot shall contain circumferential reinforcement. This