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Standard Specification for Manufacture of Precast Reinforced Concrete Three-Sided Structures for Culverts and Storm Drains (Metric)[1]

This standard is issued under the fixed designation C1504M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers single-cell precast conventionally reinforced concrete three-sided structures intended to be used for the construction of culverts and for the conveyance of storm water.

1.2 This specification is the metric counterpart of Specification C1504; therefore, no imperial (metric) equivalents are presented in this specification.

NOTE 1—This specification is primarily a manufacturing and purchasing specification. The successful performance of this product depends upon the proper selection of the geometric section, bedding, backfill, and care that the installation conforms to the construction specifications. The purchaser of the precast reinforced concrete three-sided structure specified herein is cautioned that proper correlation of the loading conditions and the field requirements with the geometric section specified and provisions for inspection at the construction site are required.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C33/C33M Specification for Concrete Aggregates

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C150/C150M Specification for Portland Cement

C260/C260M Specification for Air-Entraining Admixtures for Concrete

C309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete

C494/C494M Specification for Chemical Admixtures for Concrete

C497M Test Methods for Concrete Pipe, Manhole Sections, or Tile (Metric)

C595/C595M Specification for Blended Hydraulic Cements

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

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 *AASHTO Standard:*

AASHTO LRFD Bridge Design Specifications[3]

2.3 *ACI Standard:*

ACI 318 Building Code Requirements for Structural Concrete and Commentary[4]

3. Terminology

3.1 *Definitions*—For definitions of terms, see Terminology C822.

[1] This specification is under the jurisdiction of ASTM Committee C13 on Concrete Pipe and is the direct responsibility of Subcommittee C13.07 on Acceptance Specifications and Precast Concrete Box Sections.

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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 Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.

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

4. Types

4.1 Precast reinforced concrete three-sided structures manufactured in accordance with this specification shall be designated by span, rise, and design earth cover.

5. Basis of Acceptance

5.1 Acceptability of the three-sided sections produced in accordance with Section 7 shall be determined by the results of the concrete compressive strength tests described in Section 10, by the material requirements described in Section 6, and by inspection of the finished three-sided sections.

5.2 Three-sided sections shall be considered ready for acceptance when they conform to the requirements of this specification.

6. Materials

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 Materials:*

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 *Fly Ash*—Fly ash shall conform to the requirements of Specification C618, Class F or Class C.

6.2.3 *Slag Cement*—Slag cement shall conform to the requirements of Grade 100 or 120 of Specification C989/C989M.

6.2.4 *Allowable Combinations of Cementitious Materials*—The combination of cementitious materials used in 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 fly ash,

6.2.4.6 A combination of portland cement or portland-limestone cement and slag cement,

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 Specification C33/C33M, except that the requirements 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.

6.4.5 *Air Entraining Admixtures*—Air entraining will be required on all products produced with positive slump, wet-cast concrete, and shall conform to the requirements of Specification C260/C260M.

6.5 *Steel Reinforcement*—Reinforcement shall consist of welded wire reinforcement conforming to Specification A1064/A1064M for steel wire and welded wire reinforcement, plain and deformed, for concrete. For circumferential reinforcement, deformed and plain steel bars for reinforced concrete are permitted conforming to Specification A706/A706M or A615/A615M, Grade 420, and longitudinal distribution reinforcement shall consist of welded wire reinforcement or deformed billet-steel bars conforming to Specification A706/A706M or A615/A615M, Grade 420.

NOTE 2—This specification does not address reinforcement with prestressing strand or any other form of pre-tensioning or post-tensioning.

6.6 *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.

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

7. Design

7.1 *Design Criteria*—The three-sided section's dimensions and reinforcement details shall be as required by design, in accordance with Section 3, 5, and 12.14 of the American Association of State Highways and Transportation Officials (AASHTO) LRFD Bridge Design Specifications. The minimum concrete compressive strength shall be 35 MPa, and the minimum steel yield strength shall be 450 MPa for welded-wire reinforcement and 420 MPa for deformed billet-steel bars.

7.2 *Placement of Reinforcement*—The minimum cover of concrete over the circumferential reinforcing diameter shall be 25 mm for bar reinforcement and welded wire reinforcement for all structures up to 3.6 m in span and 38 mm for longer spans subject to provisions of Section 11 for both bar reinforcement and welded wire reinforcement. The clear distance of the end circumferential wires shall be not less than 13 mm nor more than 50 mm from the ends of each section. For three-sided sections covered by less than 0.6 m of fill, minimum cover for the reinforcement in the top of the top slab shall be 50 mm, subject to the provisions of Section 11. Reinforcement shall be assembled utilizing any combination of single or multiple layers of welded-wire reinforcement, not to exceed three layers or utilizing single or multiple layers of deformed billet steel bars, not to exceed two layers. The welded-wire reinforcement on 7.3 shall be composed of circumferential and longitudinal wires meeting the spacing requirements of 7.3 and shall contain sufficient longitudinal

wires extending through the three-sided section to maintain the shape and position of reinforcement. Longitudinal distribution reinforcement may be welded-wire reinforcement or deformed billet-steel bars and shall meet the spacing requirements of 7.3. The ends of the longitudinal distribution reinforcement shall not be more than 50 mm from the ends of a three-sided section. The exposure of the ends of longitudinals, stirrups, and spacers used to position the reinforcement shall not be a cause for rejection.

7.3 *Laps, Welds, and Spacing*—Splices in the circumferential reinforcement shall be made by lapping. For welded wire reinforcement, the overlap measured between the outermost longitudinal wires of each reinforcement sheet or the outermost bars shall not be less than the spacing of the longitudinal wires plus 50 mm but not less than 250 mm. For splices of deformed billet steel bars, the overlap shall meet the requirements of AASHTO. The outside circumferential reinforcement in the top slab shall be continuous with or be lapped with the outside circumferential reinforcement in the sides. If welds are made to welded wire reinforcement circumferential reinforcement, they shall be made only to selected circumferential wires that are not less than 450 mm apart along the longitudinal axis of the three-sided section. When spacers are welded to circumferential wires, they shall be welded only to these selected circumferential wires. There shall be no welding to other circumferential wires. No welds shall be made to the inside circumferential wires in the middle third of the top span. No welds shall be made to the outside circumferential wires in the top span within one fourth of the span from the corners or in any location in either leg. Welding of deformed billet steel bar circumferential reinforcement is prohibited in all cases. When distribution reinforcement is to be fastened to a cage by welding, it shall be welded only to longitudinal wires or bars and only near the ends of the three-sided section. The spacing center to center of the circumferential (wires) reinforcement shall not be less than 50 mm nor more than 100 mm for welded wire reinforcement or less than 50 mm nor more than 200 mm for deformed billet steel bars. The spacing center to center of the longitudinal reinforcement shall not be more than 200 mm for welded wire reinforcement or more than 300 mm for deformed billet steel bars. If welds are made to Grade 420 reinforcing bars, weldable bars conforming to Specification A706/A706M shall be used.

8. Joints

8.1 The precast reinforced concrete three-sided structures shall be produced with tongue and groove ends, flat butt ends or key-way ends. The ends shall be of such design and the ends of the three-sided sections so formed that each section can be laid together to make a continuous line of sections compatible with the permissible variations given in Section 11.

9. Manufacture

9.1 *Mixture*—The aggregates shall be sized, graded, proportioned, and mixed with cementitious materials and water and admixture, if any, to produce a thoroughly mixed concrete of such quality that the structures will conform to the design requirements of this specification. All concrete shall have a water-cementitious materials ratio not exceeding 0.53 by weights except that for concrete exposed to cyclic freeze/thaw the water-cementitious materials ratio shall not exceed 0.45. Cementitious materials shall be as specified in 6.2 and shall be added to the mix in a proportion not less than 280 kg/m^3 unless mix designs with a lower cementitious materials content demonstrate that the quality and performance of the three-sided sections meet the requirements of this specification. Wet cast concrete subject to freeze/thaw cycle shall be air-entrained. Air entrainment amounts shall be in accordance with ACI 318-11, Chapter 4, for the appropriate Exposure Class.

9.2 *Curing*—The three-sided sections shall be cured for a sufficient length of time so that the concrete will develop the required compressive strength by the time of delivery. Any one of the following methods of curing or combinations thereof may be used:

9.2.1 *Steam Curing*—The three-sided section may be low pressure, steam-cured by a system that will maintain a moist atmosphere.

9.2.2 *Water Curing*—The three-sided section may be water-cured by any method that will keep the sections moist.

9.2.3 *Membrane Curing*—A sealing membrane conforming to the requirements of Specification C309 may be applied and shall be left intact until the required concrete compressive strength is attained. The concrete temperature at the time of application shall be within 6°C of the atmospheric temperature. All surfaces shall be kept moist prior to the application of the compounds and shall be damp when the compound is applied.

9.3 *Forms*—The forms used in manufacture shall be sufficiently rigid and accurate to maintain the three-sided section dimensions within the permissible variations given in Section 11. All casting surfaces shall be smooth nonporous material.

9.4 *Handling*—Handling devices or holes shall be permitted in each three-sided section for the purpose of handling and laying.

10. Physical Requirements

10.1 *Type of Test Specimen*—Compression tests for determining concrete compressive strength shall be made on either standard rodded concrete cylinders or concrete cylinders compacted and cured in like manner as the three-sided section, or on cores drilled from the three-sided section.

10.2 *Compression Testing of Cylinders:*

10.2.1 Cylinders shall be obtained and tested for compressive strength in accordance with the provisions of Practice C31/C31M and Test Method C39/C39M, except that the cylinders may be prepared by methods comparable to those used to consolidate and cure the concrete in the actual three-sided section manufactured. Cylindrical specimens of sizes other than 150 by 300 mm may be used provided all other requirements of Practice C31/C31M are met. If the concrete is of a consistency too stiff for compaction by rodding or internal vibration, the alternate method described in Section II of Test Methods C497M may be used. Cylinders shall be exposed to similar curing time and temperature conditions as the manufactured three-sided sections as demonstrated upon request by manufacturer cylinder and three-sided section curing records.

10.2.2 Prepare no fewer than three test cylinders from each day's production of the lot of three-sided sections.

10.2.3 *Acceptability on the Basis of Cylinder Test Results:*

10.2.3.1 When the average compressive strength of all cylinders tested is equal to or greater than the design concrete strength, and 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 lot shall be accepted.

10.2.3.2 When the compressive strength of the cylinders tested does not conform to the acceptance criteria stated in 10.2.3.1, the acceptability of the lot shall be determined in accordance with the provisions of 10.3.

10.3 *Compression Testing of Cores:*

10.3.1 Cores shall be obtained, prepared and tested for compressive strength in accordance with the provisions of Test Methods C497M.

10.3.2 Three cores shall be taken from three sections (one core from each) selected at random from each group of 15 three-sided sections or fraction thereof of a single size from each continuous production run.

10.3.3 *Acceptability by Core Tests:*

10.3.3.1 The compressive strength of the concrete, as defined in 10.1, for each group of three-sided sections is acceptable when the test strength, defined as the average of three cores taken at random from the subject group, is equal to or greater than 85 % of the specified strength and no single core is less than 75 % of the specified strength.

10.3.3.2 If the compressive strength of the three cores does not meet the requirements of 10.3.3.1, the sections from which the cores were taken shall be rejected. Two three-sided sections from the remainder of the group shall be selected at random and one core shall be taken from each. If both cores have strength equal to or greater than 85 % of the specified strength of the concrete, the remainder of the group is acceptable. If the compressive strength of either of the two cores tested is less than 85 % of the specified strength of the concrete, the remainder of the group of three-sided sections shall be rejected or, at the option of the manufacturer, each three-sided section of the entire group shall be cored and accepted individually, and any of these three-sided sections that have cores with less than 85 % of the specified strength of the concrete shall be rejected.

10.4 *Plugging Core Holes*—The core holes shall be plugged and sealed by the manufacturer in a manner such that the three-sided section will meet all of the test requirements of this specification. Three-sided sections so sealed shall be considered as satisfactory for use.

10.5 *Test Equipment*—Every manufacturer furnishing three-sided sections under this specification shall furnish all facilities and personnel necessary to carry out the tests required.

11. Permissible Variations

11.1 *Internal Dimensions*—The internal dimension shall not vary more than one percent or 50 mm, whichever is less, from the design dimensions. The haunch dimensions shall not vary more than 20 mm from the design dimensions.

11.2 *Slab and Wall Thickness*—The slab and wall thickness shall not be less than that shown in the design by more than 5 % or 13 mm, whichever is greater. A thickness more than that required in the design shall not be a cause for rejection if proper joining is not affected.

11.3 *Length of Opposite Surfaces*—Variations in laying lengths of two opposite surfaces of the three-sided section shall not be more than 20 mm, except where beveled ends for laying of curves are specified by the purchaser.

11.4 *Position of Reinforcement*—Maximum variation in the position of the reinforcement for 130 mm or less, for slab and wall thickness shall be ±10 mm, and for greater than 130 mm slab and wall thickness shall be ±13 mm, and for greater than 130 mm slab and wall thickness shall be 13 mm. In no case, however, shall the cover over the reinforcement be less than 16 mm, as measured to the internal surface or the external surface except the cover over the reinforcement for the external surface of the top slab for three-sided sections with less than 0.6 m of earth cover shall not be less than 40 mm. The preceding minimum cover limitation does not apply at the mating surfaces of the joint.

11.5 *Area of Reinforcement*—The areas of steel reinforcement shall be the design steel areas, as required. Steel areas greater than those required shall not be cause for rejection. The permissible variation in diameter of any wire in finished reinforcement shall conform to the tolerances prescribed for the wire before fabrication by Specification A1064/A1064M. If steel bars (Grade 420) are used in lieu of welded wire reinforcement, the steel areas shall be increased to account for the difference in steel yield strength, steel spacing, concrete cover, and crack control between the welded wire reinforcement and steel bars.

11.6 *Haunch Dimensions*—Haunch configurations shall be as required by the design.

12. Repairs

12.1 Three-sided sections may be repaired, if necessary, because of imperfections in manufacture or handling damage and will be acceptable if, in the opinion of the purchaser, the repaired three-sided section conforms to the requirements of this specification.

13. Inspection

13.1 The quality of materials, the process of manufacture, and the finished three-sided sections shall be subject to inspection by the purchaser.

14. Rejection

14.1 Three-sided structures shall be subject to rejection on account of failure to conform to any of the specification requirements. Individual three-sided structures may be rejected because of any of the following:

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

14.1.2 Defects that indicate mixing and molding, not in compliance with 9.1, or honeycombed or open texture that would adversely affect the function of the box sections, and

14.1.3 Damaged ends, where such damage would prevent making a satisfactory joint.

15. Product Marking

15.1 The following information shall be legibly marked on each three-sided structure by indentation, waterproof paint, or other approved means.

15.1.1 Three-sided structure span, rise, maximum and minimum design earth cover, and specification designation,

15.1.2 Date of manufacture, and

15.1.3 Name or trademark of the manufacturer.

16. Certification

16.1 When agreed upon in writing by the owner and manufacturer, a certification shall be made the basis of acceptance. This certification shall consist of a copy of a sealed "stamped" design by a professional engineer in accordance with the provisions of Section 7, and a copy of the manufacturers test report or a statement by the manufacturer accompanied by the test results that the structure has been sampled, tested, and inspected in accordance with the provisions of Section 4. Each certification so furnished shall be signed by an authorized agent of the manufacturer. The owner shall be responsible for certifying that the foundation design and installation details are adequate to resist the restraint conditions assumed for analysis and the vertical and lateral forces from the analysis of the structure.

17. Keywords

17.1 AASHTO; LRFD; three-sided structures