Designation: C655 – 12b

StandardSpecification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe[1]

This standard is issued under the fixed designation C655; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This specification covers reinforced concrete pipe designed for specific D-loads and intended to be used for the conveyance of sewage, industrial wastes, and storm water and for the construction of culverts.

1.2 A complete metric companion to Specification C655 has been developed—Specification C655M; therefore, no metric equivalents are presented in this specification.

NOTE 1—Experience has shown that the successful performance of this product depends upon the proper selection of the pipe strength, the type of bedding and backfill, the care that the installation conforms to the construction specifications, and provision for adequate inspection at the construction site. This specification does not include requirements for bedding, backfill, the relationship between field load conditions and the strength designation of pipe, or durability under unusual environmental conditions. These requirements should be included in the project specification.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A36/A36M Specification for Carbon Structural Steel
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
C150 Specification for Portland Cement
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
C822 Terminology Relating to Concrete Pipe and Related Products
C989 Specification for Slag Cement for Use in Concrete and Mortars
C1116 Specification for Fiber-Reinforced Concrete and Shotcrete
E105 Practice for Probability Sampling of Materials

3. Terminology

3.1 *Definitions*—For definitions of terms relating to concrete pipe, see Terminology C822.

4. Basis of Acceptance

4.1 The acceptability of the pipe design shall be determined in accordance with Section 9. After the pipe design has been accepted, or if the pipe design has been accepted previously in accordance with Section 9, the owner may select and have applied the basis of acceptance described in either 4.1.1 or 4.1.2. Unless designated by the owner at the time of, or before placing an order, either basis of acceptance shall be permitted.

4.1.1 *Acceptance on the Basis of Pipe Load and Material Tests and Inspection of Manufactured Pipe for Defects*—Determine in accordance with Sections 5, 6, 8, and 10.

NOTE 2—It is necessary that samples be selected at random. For guidance see Practice E105.

4.1.2 *Acceptance on the Basis of Concrete Compression and Materials Tests and Inspection of Manufactured Pipe for Defects*—Determine in accordance with Sections 5, 6, 8 and 11.

4.2 *Age for Acceptance*—Pipe shall be considered ready for acceptance when they conform to the requirements.

5. Design and Manufacturing Data

5.1 The manufacturer shall provide the following information regarding the pipe unless waived by the owner:

5.1.1 Basis of acceptance.

5.1.2 Pipe design strength.

5.1.3 *Physical Characteristics*—Diameter, wall thickness, laying length, and joint details.

[1] This specification is under the jurisdiction of ASTM Committee C13 on Concrete Pipe and is the direct responsibility of Subcommittee C13.02 on Reinforced Sewer and Culvert Pipe.

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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.

5.1.4 Design concrete strength; minimum $f`_c$ equals 4000 psi.

5.1.5 Admixtures.

5.1.6 *Reinforcement:*

5.1.6.1 Type of reinforcement, applicable reinforcement specification, and grade.

5.1.6.2 Placement, placement tolerances, diameter, spacing and cross-sectional area of circumferential, longitudinal, and special reinforcement.

5.1.7 Manufacturing and curing process.

6. Materials and Manufacture

6.1 *Materials:*

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

6.1.2 *Cementitious Materials:*

6.1.2.1 *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.

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

6.1.2.3 *Ground Granulated Blast-Furnace Slag (GGBFS)*—GGBFS shall conform to the requirements of Grade 100 or 120 of Specification C989.

6.1.2.4 *Allowable Combinations of Cementitious Materials*—The combination of cementitious materials used in the cement shall be one of the following:

(1) Portland cement only,

(2) Portland blast furnace slag cement only,

(3) Slag modified Portland cement only,

(4) Portland pozzolan cement only,

(5) A combination of portland cement and fly ash,

(6) A combination of portland cement and ground granulated blast-furnace slag,

(7) A combination of portland cement, ground granulated blast-furnace slag, and fly ash, or

(8) A combination of portland pozzolan cement and fly ash.

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

6.1.4 *Admixtures and Blends*—Admixtures and blends shall be allowed to be used unless prohibited by the owner.

6.1.5 *Steel Reinforcement*—Reinforcement shall conform to the requirements of Specification A1064/A1064M, or bars conforming to Specification A36/A36M, Specification A615/A615M Grade 40 or 60, or Specification A706/A706M Grade 60. For helically wound cages only, weld shear tests are not required.

6.2 *Manufacture:*

6.2.1 *Mixture*—The aggregates shall be sized, graded, proportioned, and mixed with such proportions of cementitious materials and water as will produce a homogeneous concrete mixture 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. Cementitious materials shall be as specified in 6.1 and shall be added to the mix in a proportion not less than 470 lb/yd^3 unless mix designs with a lower cementitious material content demonstrate that the quality and performance of the pipe meet the requirements of this specification.

6.2.2 *Reinforcement:*

6.2.2.1 *Placement*—Reinforcement shall be placed as indicated in 5.1.6.2, subject to the tolerances given in 8.2.2. Minimum design protective cover of concrete over the circumferential reinforcement in the barrel of the pipe shall be 1 in. for wall thicknesses of 2½ in. or greater, and ¾ in. for wall thicknesses less than 2½ in., subject to the tolerances given in 8.2.2.

6.2.2.2 *Splices*—The strength of the pipe shall not be adversely affected by the splice.

6.2.2.3 *Spacing*—The spacing center-to-center of adjacent rings of circumferential reinforcement in a cage shall not exceed 4 in. for pipe with a wall thickness up to and including 4 in. and shall not exceed the wall thickness or 6 in., whichever is smaller, for larger pipe.

6.2.3 *Joints*—The joints shall be of such design and the ends of the concrete pipe sections so formed that when the sections are laid together they will make a continuous line of pipe with a smooth interior free of appreciable irregularities in the flow line, all compatible with the permissible variations given in Section 8.

6.2.4 *Lift Holes*—When agreed upon by the owner, lift eyes or holes shall be allowed to be provided in each pipe for the purpose of handling.

6.3 *Synthetic Fibers*— Collated fibrillated virgin polypropylene fibers shall be allowed to be used, at the manufacturer's option, in concrete pipe as a nonstructural manufacturing material. Only Type III synthetic fibers designed and manufactured specifically for use in concrete and conforming to the requirements of Specification C1116 shall be accepted.

7. Physical Requirements

7.1 *Strength*—The design strength designation of the pipe shall be the D-load to produce the 0.01-in. crack when tested in accordance with Test Methods C497. The relationship of ultimate strength D-load to the design strength D-load shall be determined using a factor of 1.5 for design strength designations up to 2000 lbf/ft·ft of diameter, a factor varying in linear proportions from 1.5 to 1.25 for design strength designations from 2000 through 3000, and a factor of 1.25 for design strength designations in excess of 3000.

NOTE 3—As used in this specification, the 0.01-in. crack is a test criterion for pipe tested in three-edge bearing test and is not intended as an indication of overstressed or failed pipe under installed conditions.

NOTE 4—Ultimate strength of concrete pipe in the buried condition is dependent on varying soil bedding factors and varying failure modes and shall not necessarily have a relationship to the ultimate strength as defined under three-edge bearing conditions.

7.2 *Test Equipment and Facilities*—The manufacturer shall furnish without charge all samples, facilities, and personnel necessary to carry out the tests required by this specification.

7.3 *Pipe Load Tests*— The tests for crushing strength, when required, shall be made in accordance with Test Methods C497. When alternative methods of load testing are specified, tests shall be made in accordance with the alternative requirements.

8. Dimensions and Permissible Variations

8.1 *Standard Diameters*—Pipe shall be manufactured in the standard inside diameters listed in Table 1.

NOTE 5—Diameters other than those shown in Table 1 and diameters larger than 144 in. are possibly available. When such sizes are required, the owner should contact the manufacturers in the area.

8.2 *Design Tolerances*—Except as specified in this section, all permissible design tolerances shall be given in Section 5.

8.2.1 *Internal Diameter*—The internal diameter of 12 through 24-in. pipe shall not vary more than 2 % of the design diameter for 12-in. pipe and 1½ % for 24-in. pipe with intermediate size variation being a linear scale between 2 and 1½ %. The internal diameter of sizes 27-in. and larger shall not vary by more than 1 % of the design diameter or ±⅜-in., whichever is greater. These diameter requirements are based on the average of four diameter measurements at a distance of 12-in. from the end of the bell or spigot of the pipe. Diameter verification shall be made on the number of pipe selected for test per Section 11.

8.2.2 *Reinforcement Placement Tolerances*—The maximum variation in the nominal position of the reinforcement shall be ±10 % of the wall thickness or ±⅝ in., whichever is greater. Pipe having variations in the position of the reinforcement exceeding those specified above shall be accepted if the three-edge-bearing strength requirements obtained on a representative sample are met. In no case, however, shall the cover over the circumferential reinforcement be less than ⅝ in.

8.2.3 *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 ⅛ in./ft of internal diameter for all larger sizes, with a maximum of ⅝ 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.

8.2.4 *Length of Pipe*—The underrun in length of a section of pipe shall not be more than ⅛ in./ft with a maximum of ½ in. in any length of pipe.

8.2.5 *Wall Thickness Tolerances*—The wall thickness shall be not less than the nominal specified in the design given in 5.1.3 by more than 5 % or 3⁄16 in., whichever is greater. A wall thickness more than that required in the design is not a cause for rejection, except that such pipe shall not be used for the tests required in 7.3.

9. Acceptance of Design

9.1 *Acceptance by Tests of Specimens*—Three to five representative specimens, or special test pipe that are shorter than standard production pipe, as agreed upon by the owner and manufacturer, shall be tested to the 0.01-in. crack and to ultimate strength and the results recorded. Compute the values in 9.1.1 and 9.1.2 for both the 0.01-in. crack and the ultimate strength.

9.1.1 Compute the estimated standard deviation, s, by Eq 1 or Eq 2, which equations yield identical values.

$$s = \sqrt{\left[\sum\left(X_i - \bar{X}\right)^2\right]/(n-1)} \quad (1)$$

$$s = \sqrt{\left[\sum X_i^2 - \left(\sum X_i\right)^2/n\right]/(n-1)} \quad (2)$$

where:

X_i = observed value of the load to produce the 0.01-in. crack (and the load to develop the ultimate strength),
$\bar{X}$ = average (arithmetic mean) of the values of X_i, and
n = number of observed values.

9.1.2 Compute the minimum allowable arithmetic mean, $\bar{X}_s$, by Eq 3. In Eq 3, the value of the estimated standard deviation, s, shall be as calculated by Eq 1 or Eq 2 or equal to 0.07L, whichever is greater.

$$\bar{X}_s = L + 1.07\,s \quad (3)$$

where:

L = specification limit (specified D-load).

9.1.3 The pipe design shall be acceptable if the arithmetic mean $\bar{X}$ for the 0.01-in. crack and ultimate strength is equal to or greater than the computed values of $\bar{X}_s$, and if all the tested specimens meet or exceed the specification limit, or if all test specimens meet or exceed the design strength.

9.2 *Alternative Acceptance Method*—The manufacturer shall be allowed to request approval of designs based on empirical evaluations of the strength of the pipe including, but not limited to, designs based on interpolation between designs approved in accordance with 9.1, or designs evaluated on the basis of tests other than the three-edge-bearing test method. Acceptance of design tests need not be performed for each contract or order.

10. Acceptance of Pipe by Load Testing

10.1 *Lot Sampling*—When the acceptance is to be in accordance with 4.1.1, randomly select from the lot a sample of the size listed in Table 2 and test each specimen to the 0.01-in. crack. When all specimen test strengths are greater than the minimum design strength D-load, the lot shall be accepted. When one or more specimen test strengths are less than the minimum design strength D-load, the values for $\bar{X}$ and s shall be computed and substituted into the applicable equation given in Table 2. When the arithmetic mean $\bar{X}$ is equal to or greater than the computed value of $\bar{X}_s$, the lot of pipe shall be

TABLE 1 Standard Designated Inside Diameter, in.

12	24	36	60	84	108	132
15	27	42	66	90	114	138
18	30	48	72	96	120	144
21	33	54	78	102	126	

TABLE 2 Sample Size

Lot Size	Sample Size	Equation	Equation Number
0 to 300	3	$\bar{X}_s = L + 1.08\,s$	(4)
301 to 500	4	$\bar{X}_s = L + 1.09\,s$	(5)
501 to 800	5	$\bar{X}_s = L + 1.10\,s$	(6)
801 to 1300	7	$\bar{X}_s = L + 1.16\,s$	(7)