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Standard Specification for Steel Fiber Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe[1]

This standard is issued under the fixed designation C1765; 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 steel fiber reinforced concrete pipe (SFRCP) ~~of internal diameters 12 - 48 in.,~~ intended to be used for the conveyance of sewage, industrial wastes, and storm water and for the construction of culverts.

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 relation ship 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.

1.2 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A820/A820M Specification for Steel Fibers for Fiber-Reinforced Concrete
C33/C33M Specification for Concrete Aggregates
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, Concrete Box Sections, Manhole Sections, or Tile
C595/C595M Specification for Blended Hydraulic Cements
C618 Specification for Coal 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 (Withdrawn 2022)[3]
C1602/C1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

[1] This test method 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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

***A Summary of Changes section appears at the end of this standard**

E105 Guide for Probability Sampling of Materials

3. Terminology

3.1 *Definitions*—For definitions of terms relating to concrete pipe not defined in this specification, see Terminology C822.

3.2 $D_{Service}$—the D_{Test} test load divided by a factor of safety of 1.5.

3.3 D_{Test}—the load the pipe is required to support in the three-edge bearing test expressed as a D-load.

4. Classification

4.1 Pipe furnished under this specification shall be designated as Class I, II, III, IV, or V. The corresponding strength requirements are prescribed in Table 1. Special designs for pipe strengths not designated in Table 1 are permitted, provided all other requirements of this specification are met.

TABLE 1 Pipe Strength Requirements

Pipe Class	$D_{Service}$ (lb/linear foot/ foot of diameter)	D_{Test} (lb/linear foot/foot of diameter)
I	800	1200
II	1000	1500
III	1350	2025
IV	2000	3000
V	3000	4500

4.2 Current industry practices have provided proof testing for sizes and classes shown in Table 1a and can be considered commonly available. Additional sizes and classes meeting test requirements of this standard may be possible but must be verified with local producers prior to specification on a project.

TABLE Table 1a—Commonly Available Sizes/Classes

Class 1 – 12" through 48"
Class 2 – 12" through 48"
Class 3 – 12" through 42"
Class 4 – 12" through 36"
Class 5 – 12" through 36"

5. Basis of Acceptance

5.1 The acceptability of the pipe design shall be in accordance with Section 9.

5.2 Unless designated by the owner at the time of, or before placing an order, the pipe shall be accepted on the basis of Sections 10 and 11, and such material tests as are required in 7.2, 7.3, and 7.5.

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

6. Design and Manufacturing

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

6.1.1 Pipe design strength ($D_{Service}$).

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

6.1.3 *Steel Fiber Concrete Compressive Strength*—Minimum steel fiber concrete compressive strength equal to 4000 psi.

6.1.4 Admixtures.

6.1.5 *Reinforcement:*

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

6.1.5.2 Percentage of steel fiber reinforcing by volume.

6.1.6 Manufacturing and curing process.

7. Materials and Manufacture

7.1 *Materials:*

7.1.1 *Steel Fiber Reinforced Concrete*—The steel fiber reinforced concrete shall consist of cementitious materials, mineral aggregates, admixtures, if used, and water, in which steel fibers have been mixed in such a manner that the steel and concrete act together to resist stresses.

7.2 *Cementitious Materials:*

7.2.1 *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.

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

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

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

7.2.4.1 Portland cement only,

7.2.4.2 Portland blast-furnace slag cement only,

7.2.4.3 Portland-pozzolan cement only,

7.2.4.4 Portland-limestone cement only,

7.2.4.5 A combination of portland cement or portland-limestone cement and fly ash,

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

7.2.4.7 A combination of portland cement or portland-limestone, slag cement and fly ash, or

7.2.4.8 A combination of portland pozzolan cement and fly ash.

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

7.4 *Admixtures and Blends*—The following admixtures and blends are allowable.

7.4.1 Air-entraining admixture conforming to Specification C260/C260M;

7.4.2 Chemical admixture conforming to Specification C494/C494M;

7.4.3 Chemical admixture for use in producing flowing concrete conforming to Specification C1017/C1017M; and

7.4.4 Chemical admixture or blend approved by the owner.

7.5 *Steel Reinforcement*—Reinforcement shall consist of steel fibers conforming to Specification A820/A820M.

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

7.7 *Manufacture:*

7.7.1 *Mixture*—The aggregates shall be sized, graded, proportioned, and mixed with such proportions of cementitious materials, steel fibers, admixtures, and water as will produce a thoroughly mixed steel fiber 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. Cementitious materials shall be as specified in 7.2.

7.7.2 *Reinforcement*—Steel reinforcing fibers shall be thoroughly mixed throughout the concrete amalgam. No restriction is placed on the combination or proportion of steel fibers in the finished product, except that pipes manufactured using these materials and mixture shall comply with the performance requirements of this standard.

7.7.3 *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 11.

8. Design

8.1 *Design*—The wall thickness, compressive strength of the concrete, and percentage of steel fibers by volume shall be sufficient to pass the D_{Test} requirements in Table 1.

8.2 *Special Classes:*

8.2.1 If permitted by the owner, the manufacturer may request approval by the owner of a special class of pipe having D_{Test} values that differ from those shown in Table 1.

8.2.2 Such special classes of pipe shall be based on the same design/testing requirements as required for those classes found in Table 1.

9. Proof of Design Testing

9.1 *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.

9.2 *Proof of Design*—When testing for proof of design, the pipe tests shall be conducted in accordance with Test Methods C497. Prior to loading, measure the vertical internal diameter of each end of the pipe. Load on the pipe shall increase continuously until it reaches the ultimate load without collapse due to residual strength provided by the steel-fiber matrix. The D_{ult} value shall be ~~recorded.~~ recorded and shall not be less than the D_{ult} value prescribed in Table 1 for each respective class of pipe..

9.3 *Proof of Bond/Ductility/Toughness*—After the proof of design test, the pipe shall ~~be immediately unloaded and reloaded in accordance with Test Method~~continue to be subjected to increased loading and/or deflection until the inside ~~C497.~~ diameter has reduced vertically at either end by at least 2 % of the internal diameter. As a verification of bond, ductility, and toughness, the pipe shall be loaded until it reaches ~~the specified service load,~~2 % deflection. Record the peak load (D_p ~~D~~) between$_{Service}$. 1 % and 2 % deflection as follows:

D_p = the peak load applied over a range of 1 % to 2 % deflection (lb/ft/ft). D_p shall exceed the required service load ($D_{service}$).

NOTE 2—This test ensures the fibers have both the anchorage and tensile strength to continue to behave in a ductile, not brittle ~~manner.~~manner to a performance level sufficient to guarantee the long-term performance of the pipe throughout the 1 % to 2 % deflection according to typical rigid design assumptions.

9.4 *Establishment of Pipe Strength:*

9.4.1 Three to seven representative specimens, of standard production pipe, shall be tested to their ultimate load, and the results recorded. Using the values obtained in 9.2, compute the values in 9.4.2 and 9.4.3.

NOTE 3—It is necessary that samples be selected at random. For guidance see Practice E105.

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

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

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

where:

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

9.4.3 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 0.07 L, whichever is greater.

$$\bar{X}_s = L + S_m \quad (3)$$

L = specification limit (specified D-load) and
S_m = modified standard deviation dependent upon sample size (see Table 2).

9.4.4 The pipe shall be deemed acceptable if the arithmetic mean $\bar{X}$ for the D_{ult} strength value is equal to or greater than $\bar{X}_s$.

9.5 *Sample Testing of Pipe Strength*—If any part of the material or manufacture of the pipe are modified, then the ability of the pipe to meet the required D_{Test} ~~value~~ and D_p values shall be reestablished in accordance with 9.4. Provided there is no change in material or manufacture of the pipe used to establish the pipe class, pipe shall be periodically tested in accordance with Section 10 for quality assurance.

10. Physical Requirements

10.1 The proof of design is as required in accordance with 9.2. The test requirements of this section apply to the quality assurance of pipe production with the pipe being tested to D_{Test} (150 % of the $D_{Service}$~~).~~) and D_p~~.~~

10.2 *Test Specimens*—The pipe required for tests shall be furnished by the manufacturer, selected at random, and shall be pipe that would otherwise not be rejected under this specification.

10.3 *External Load Test Strength*—The load to produce the D_{Test} Load as determined by the three-edge-bearing method described in the Test Methods C497 shall not be less than that prescribed in Table 1 for each respective class of pipe. It is not a requirement of this section that the pipe be loaded to its D_{ult} strength. Section 9 does test the pipe to D_{ult}.

10.4 *Number and Tests Required for Pipe Test Load*—The pipe producer shall perform a three-edge bearing test in accordance with Test Methods C497 and the provisions in 10.2. The test shall be performed on one pipe per production run, as defined in Terminology C822, or every 200 pieces of like size and class of pipe, whichever is less.

NOTE 4—While cracks may occur in steel fiber reinforced concrete pipe, they are not to be considered an indication of overstressed or failed pipe provided the pipe meets all other performance requirements of this specification.

10.5 *Retests of Pipe*—If any pipe fails to pass the three-edge bearing test requirements, then three more pipe shall be selected at random from the same production run and tested. If all three pipes pass, then the pipe from that production run is acceptable. If any pipe fails to meet the test requirements, the required tests shall be made on the balance of the order and the pipe shall be accepted if they conform to the requirements of this specification.

10.6 *Absorption*—An annual absorption test shall be perfortned for each mix design for each production process. The absorption of a sample from the wall of the pipe, as determined in accordance with Test Methods C497, shall not exceed 9 % of the dry mass for Method A or 8.5 % for Method B. Each Method A sample shall have a minimum mass of 2.2 lb (1.0 kg), shall be free of visible cracks, and shall represent the full wall thickness of the pipe. When the initial absorption sample from the pipe fails to conform to this specification, the absorption test shall be made on another sample from the same pipe and the results of the retest shall be substituted for the original test results.

CONCRETE TESTING

10.7 *Type of Specimen*—Compression tests for determining steel fiber concrete compressive strength shall be allowed to be made on either concrete cylinders or on cores drilled from the pipe.

10.8 *Compression Testing of Cylinders:*

10.8.1 *Cylinder Production*—Cylinders shall be prepared in accordance with the cylinder strength test method of Test Methods C497.

TABLE 2 Modified Standard Deviation Values

Sample Size (*n*)	S_m Value
3	1.08s
4	1.09s
5	1.10s
7	1.16s