Designation: C1765 – 16

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.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A820/A820M Specification for Steel Fibers for Fiber-Reinforced Concrete
C33 Specification for Concrete Aggregates
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
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
C1602/C1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
E105 Practice 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.

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.

[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.

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

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 or shall be portland blast-furnace slag cement, portland-limestone 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.

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.

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, 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;

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. 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.

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 C497. As a verification of bond, ductility, and toughness, the pipe shall be loaded until it reaches the specified 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.

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.

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

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

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 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 $D_{Service}$).

TABLE 2 Modified Standard Deviation Values

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

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.

10.8.2 *Number of Cylinders*—Prepare not fewer than three test cylinders from each steel fiber concrete mix used within a group (one day's production) of pipe sections.

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

10.8.3.1 When the compressive strengths of all cylinders tested for a group are equal to or greater than the design steel

fiber concrete strength, the compressive strength of the steel fiber concrete in the group of pipe sections shall be accepted.

10.8.3.2 When the average compressive strength of all cylinders tested is equal to or greater than the design steel fiber concrete strength, not more than 10 % after the cylinders tested have a compressive strength less than the design steel fiber concrete strength. and no cylinder tested has a compressive strength less than 80 % of the design steel fiber concrete strength, then the group shall be accepted.

10.8.3.3 When the compressive strength of the cylinders tested does not conform to the acceptance criteria stated in 10.8.3.1 or 10.8.3.2, the acceptability of the group shall be determined in accordance with the provisions of 10.9.

10.9 *Compression Testing of Cores:*

10.9.1 *Obtaining Cores*—Cores shall be obtained, prepared, and tested in accordance with the core strength test method of Test Methods C497.

10.9.2 *Number of Cores*—Three cores shall be cut from sections selected at random from each day's production run of a single steel fiber concrete strength.

10.10 *Acceptability on the Basis of Core Test Results:*

10.10.1 The compressive strength of the steel fiber concrete, as defined in 10.7, for each group of pipe sections is acceptable when the steel fiber concrete compressive 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 required strength of the steel fiber concrete with no one core less than 75 % of the required strength.

10.10.2 If the compressive strength of the three cores does not meet the requirements of 10.10.1, the pipe from which the cores were taken shall be rejected. Three additional pipes from that lot shall be tested in three-edge bearing in accordance with 10.3. If all three pipe sections meet the D_{test} requirement the remainder of the group shall be acceptable. If any one of the three pipes does not meet the D_{test} requirement, the remainder of the group shall be rejected or, at the option of the manufacturer, each pipe section of the remaining group shall be three-edge bearing tested and accepted individually.

11. Dimensions and Permissible Variations

11.1 *Standard Diameters*—Pipe shall be manufactured in the standard inside diameters listed in Table 3. The manufacturer shall request approval by the purchaser for larger sizes.

11.2 *Internal Diameter*—The internal diameter of 12-in. through 24 in. pipe shall not vary by more than 2 % of the design diameter for 12-in. pipe and 1.5 % for 24-in. pipe with intermediate sizes variation being a linear scale between 2 % and 1.5 %. The internal diameter of sizes 21 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 in accordance with Section 10.

TABLE 3 Standard Designated Inside Diameter, in.

12	24	36
15	27	42
18	30	48
21	33	

11.3 *Wall Thickness*—The wall thickness shall be not less than the nominal specified in the design given in 6.1.2 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 pipe with a wall thickness greater than 5 % of that specified shall not be used for the tests required in Section 9.

11.4 *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 ⅛ in./ft of internal diameter for all larger sizes, with a maximum of ½ in. in any pipe through 48-in. internal diameter, except where beveled-end pipe for laying on curves is specified by the owner.

11.5 *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.

12. Repairs

12.1 Pipe shall be repaired, if necessary, because of imperfections in manufacture or damage during handling, and will be acceptable if, in the opinion of the owner, the repaired pipe conforms to the requirements of this specification.

13. Inspection

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

14. Rejection

14.1 Pipe shall be subject to rejection on account of failure to conform to any of the specification requirements. Individual sections of pipe shall be allowed to 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 proportioning, mixing, and molding, not in compliance with 7.7.1, or surface defects indicating honeycombed or open texture that would adversely affect the function of the pipe.

14.1.3 The ends of the pipe are not normal to the walls and center line of the pipe, within the limits of variations given in 11.4 and 11.5.

14.1.4 Damaged or cracked ends where such damage would prevent making a satisfactory joint.

14.2 Rust staining on the surface of the pipe, or the exposure of steel fibers, or both, is not a cause for rejection.

15. Disposition of a Rejected Lot

15.1 A lot of pipe which fails to meet the criteria for acceptability shall be allowed to be utilized in accordance with a procedure mutually agreed upon by the manufacturer and the owner. The procedure shall demonstrate improvement in the lot, statistically calculate a reduced D_{Test} strength for the lot, or

develop an acceptable disposition. The manufacturer shall bear all expenses incurred by the procedure.

16. Certification

16.1 When specified in the purchase order or contract, a manufacturer's certification shall be furnished to the owner that the products were manufactured, sampled, tested and inspected at the time of manufacture in accordance with this specification and have been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

17. Product Marking

17.1 The following information shall be legibly marked on each section of pipe:

17.1.1 ASTM Designation,

17.1.2 Pipe size,

17.1.3 Pipe class or minimum test load, whichever is specified, and specification designation,

17.1.4 Date of manufacture,

17.1.5 Name or trademark of the manufacturer, and

17.1.6 Identification of plant.

17.2 Markings shall be indented on the pipe section or painted thereon with waterproof paint or ink.

18. Keywords

18.1 circular pipe; D load; sewer pipe; SFRCP; steel fibers; storm drains; three edge bearing strength

APPENDIX

(Nonmandatory Information)

X1. EXAMPLE CALCULATION

X1.1 As required by 9.2, the strength verification of a 24-in. designated inside diameter pipe will be determined in accordance with 9.4. The test strength D_{Test} is specified as 2025 lbf/linear ft per foot of designated inside diameter (Class III pipe).

X1.2 From the lot, randomly select a sample of five specimens (n = 5) each at least 6 ft long (in this example, the pipe are all 8 feet long).

X1.3 Test the pipe to D_{ult}. Record the observed D_{ult} values of X_i in pounds-force: 38000, 32400, 37300, 35200, and 38900.

X1.4 Since in this example X_i is in pounds-force, convert the specification limit L (test strength D-load) to pounds by multiplying the D-load times the designated inside diameter in feet times the pipe length in feet, or

$$L = 2025 \times (24 \ / \ 12) \times 8 = 32400 \ \text{lbf} \qquad \text{(X1.1)}$$

X1.5 Compute the required minimum allowable value in accordance with the acceptability criteria 9.4.

X1.6 The following values for X and s must be computed (see Note X1.1):

$\bar{X}$ = average (arithmetic mean) of the observed values X_i and
s = estimated standard deviation.

NOTE X1.1—The observed values of pipe strengths will be divided by 100 to simplify the computations in accordance with the recommendation made in Section 25 of *ASTM STP 15-C*[3]. The effect is to reduce the size of the numbers so they can be computed more easily.

X1.7 Calculate the values for $\bar{X}$ as follows:

X_i	X_i^2
380	144400
324	104976
373	139129
352	123904
389	151321
$\sum X_i$ = 1818	$\sum X_i^2$ = 663730

$$(\Sigma \ X_i)^2 = (1818)^2 \qquad \text{(X1.2)}$$

$$= 3305124$$

$$\bar{X} = (\Sigma \ X_i \ / \ n) \times 100 \qquad \text{(X1.3)}$$

$$\bar{X} = (1818 \ / \ 5) \times 100$$

$$\bar{X} = 36360$$

X1.8 The standard deviation, s, shall be computed by either Eq 1 or Eq 2. Since Eq 2 is a simpler form for computation, this will be used.

$$s = \sqrt{[\Sigma \ X_i^2 \ - \ (\Sigma \ X_i)^2 \ / \ n] \ / \ (n \ - \ 1)} \qquad \text{(X1.4)}$$

$$s = \sqrt{[663730 - 3305124 \ / \ 5] \ / \ (5 \ - \ 1)}$$

$$s = \sqrt{676}$$

$$s = 26$$

X1.9 Multiply by 100 to obtain total pounds-force:

$$s = 26 \times 100 \qquad \text{(X1.5)}$$

$$s = 2600$$

The required minimum allowable arithmetic mean $\bar{X}_s$, is computed by Eq 3, using S_m = 1.10 s for five samples:

[3] *Manual on Quality Control of Materials*, *ASTM STP 15C*, ASTM, January 1951, Section 25.

$$\bar{X}_s = L + 1.10\ s \quad \text{(X1.6)}$$

$$\bar{X}_s = 32400 + 1.10 \times 2600$$

$$\bar{X}_s = 35260$$

Since the actual $\bar{X}$ of 36360 lbf is greater than the required minimum allowable $\bar{X}_s$, of 35260 lbf, the pipe material and manufacturing process result in a pipe that is verified to meet the Class III strength designation.

X1.10 *ASTM STP 15D*[4] is a valuable source of information regarding statistical procedures and simplified computational methods.

[4] *Manual on Presentation of Data and Control Chart Analysis*, *ASTM STP 15D*, ASTM, 1976