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

This standard is issued under the fixed designation C1818; 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 synthetic fiber reinforced concrete pipe ~~(Syn-FRCP) of internal diameters 12-48 in.,~~ (Syn-FRCP), 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 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.

NOTE 2—This product is a rigid pipe and it does not depend upon deflection (pipe stiffness) for additional support from the soil.

NOTE 3—This standard requires long-term testing of Syn-FRCP in accordance with Section 9 that goes above and beyond what is typically required for steel reinforced concrete pipe, in order to evaluate the long-term material strength of the fiber-concrete matrix.

1.2 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered 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]

C33/C33M Specification for Concrete Aggregates
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
C497 Test Methods for Concrete Pipe, Concrete Box Sections, Manhole Sections, or Tile
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

[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.

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

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]
C1116/C1116M Specification for Fiber-Reinforced Concrete
D7508/D7508M Specification for Polyolefin Chopped Strands for Use in Concrete
E105 Guide for Probability Sampling of Materials

3. Terminology

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

3.2 *Definitions:*

3.2.1 $D_{ReloadP}$—the $D_{Service}$ load divided by the long-term serviceability factor α as determined in accordance with Section 9. as compared to the peak test load for a range of deflection from 1 % to 2 % of the initial inside diameter.

3.2.2 $D_{Service}$—the D-Load the pipe is required to sustain while in service.

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

3.2.4 *α*—long-term serviceability factor to account for possible creep in the pipe over time (unitless).

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.

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 1A Commonly Available Sizes / Classes
Class 1 – 12 in. through 48 in.
Class 2 – 12 in. through 48 in.
Class 3 – 12 in. through 42 in.
Class 4 – 12 in. through 36 in.
Class 5 – 12 in. through 36 in.

5. Basis of Acceptance

5.1 The acceptability of the pipe design shall be in accordance with Section 10.

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 11, 12, and such material tests as are required in 7.2, 7.3, and 7.5.

TABLE 1 Strength Requirements

Pipe Class	$D_{Service}$ (lb/linear foot/foot of diameter)	D_{Ult} (lb/linear foot/foot of diameter)	D_{Reload} (lb/linear foot/foot of diameter)
Pipe Class	$D_{Service}$ (lb/linear foot/foot of diameter)	D_{Ult} (lb/linear foot/foot of diameter)	D_P (lb/linear foot/foot of diameter)
I	800	1200	$D_{Service}/\alpha$
II	1000	1500	where:
III	1350	2025	α = long-term serviceability factor as
IV	2000	3000	determined per Section 9 of this
V	3000	4500	standard

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

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 Data

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 *Synthetic Fiber Concrete Compressive Strength*—Minimum synthetic fiber concrete compressive strength equal to 4,000 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 Amount of fiber used in pounds per cubic yard.

6.1.6 Manufacturing and curing process.

7. Materials and Manufacture

7.1 *Materials:*

7.1.1 *Synthetic Fiber Reinforced Concrete*—The synthetic fiber reinforced concrete shall consist of cementitious materials, mineral aggregates, admixtures, and water, in which synthetic fibers have been mixed in such a manner that the fibers 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, or portland-pozzolan cement conforming to the requirements of Specification C595/C595M, except that the pozzolan constituent in the 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 A combination of portland cement and fly ash,

7.2.4.5 A combination of portland cement and slag cement,

7.2.4.6 A combination of portland cement, slag cement, and fly ash,

7.2.4.7 A combination of portland-pozzolan cement and slag cement, and

7.2.4.8 A combination of portland blast-furnace slag 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*—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 *Synthetic Fiber Reinforcement*—Reinforcement shall consist of synthetic fibers conforming to Specifications C1116/C1116M and D7508/D7508M.

7.6 *Manufacture:*

7.6.1 *Mixture*—The aggregates shall be sized, graded, proportioned, and mixed with such proportions of cementitious materials, synthetic fibers, admixtures, and water as will produce a thoroughly mixed synthetic 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.

7.6.2 *Curing*—Pipe shall be subjected to any one of the methods of curing described in 7.6.2.1 to 7.6.2.4 or to any other method or combination of methods approved by the owner, that will give satisfactory results. The pipe shall be cured for a sufficient length of time so that the specified D-load is obtained when tested in accordance with 11.1 to 11.4, and so that the concrete will develop the specified compressive strength at the time of delivery when tested in accordance with 11.8 to 11.10.

7.6.2.1 *Steam Curing*—Pipe may be placed in a curing chamber, free of outside drafts, and cured in a moist atmosphere maintained by the injection of steam for such time and such temperature as may be needed to enable the pipe to meet the strength requirements. The curing chamber shall be so constructed as to allow full circulation of steam around the entire pipe.

7.6.2.2 *Water Curing*—Concrete pipe may be water-cured by covering with water saturated material or by a system of perforated pipes, mechanical sprinklers, porous hose, or by any other approved method that will keep the pipe moist during the specified curing period.

7.6.2.3 The manufacturer may, at his option, combine the methods described in 7.6.2.1 to 7.6.2.4 provided the required concrete compressive strength is obtained.

7.6.2.4 A sealing membrane conforming to the requirements of Specification C309 may be applied and should be left intact until the required strength requirements are met. The concrete at the time of application shall be within 10°F 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.

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

7.6.4 *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 12.

8. Pipe Design

8.1 *Design*—The wall thickness, compressive strength of the concrete, and amount of synthetic fibers in pounds per cubic yard shall be sufficient to pass the D_{Ult} and $D_{ReloadP}$ 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 $D_{ServiceP}$ 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. Synthetic Fiber-Concrete Matrix Qualification Testing

9.1 The long-term serviceability factor α, pertaining to the extrapolated 100 year strength of the concrete-fiber matrix, shall be established in accordance with 9.7.

9.2 When tested in accordance with 9.7, the average long-term serviceability factor shall be 0.9 or higher, with no single test value less than 0.8.

9.3 The long-term serviceability testing shall be performed by an independent third-party laboratory.

9.4 The testing shall be performed on a pipe with a minimum internal diameter of 24 in., with a wall thickness in inches equal to or greater than ID/12 +1, where ID is the internal diameter measured in inches.

NOTE 4—Research has been performed on pipe sizes of 24, 36, and 48 in., with different pipe classes and has shown consistent results for α regardless of pipe size or class.

9.5 The sustained load for long-term serviceability testing shall be $D_{Service}$.

9.6 The resulting long-term serviceability factor α, shall be appropriate for all pipe sizes and strengths manufactured with the same concrete mix and fibers utilized in the testing.

9.7 *Fiber-Concrete Qualification Testing:*

9.7.1 The standard testing temperature shall be 73.4 ± 3.6°F (23 ± 2°C).

9.7.2 Pipe shall be tested in the three-edge bearing test load to its ultimate strength in accordance with Test Method C497 without collapse of the pipe.

9.7.3 The three-edge bearing load shall be completely removed from the pipe.

9.7.4 The pipe shall then be reloaded to a minimum D-load of $D_{Service}$ in a loading frame capable of applying and maintaining a three-edge bearing load perpendicular to the pipe axis throughout the test period, despite any change in the vertical diameter of the test specimen. The system shall be capable of applying and maintaining the load to ±2 % of the test load.

9.7.5 *Load Application Systems*—The test loads may be applied by hydraulic means or by springs or may be applied by the use of dead weights.

9.7.5.1 *Hydraulic Loading*—The use of a hydraulic loading system allows several specimens to be loaded simultaneously through a central hydraulic pressure regulating unit. Such a unit typically consists of an accumulator, a regulator, a calibrated pressure gauge, and a source of high-pressure, such as a cylinder of nitrogen or a high-pressure pump system.

9.7.5.2 *Dead Weight Loading*—The apparatus consists of a rigid beam placed parallel to the floor, a rigid work-arm to introduce the load with a ring on one end to attach weights, a rigid beam parallel to the floor, rigid support beams, and a drop protection for the weights.

9.7.6 The initial vertical dimension of the pipe shall be measured immediately upon applying the load. The device used for taking measurements shall have an accuracy of ±0.002 in.

9.7.7 Subsequent measurements of the vertical dimension of the pipe shall be recorded at the increments found in Table 2.

9.7.8 Recording of measurements may cease anytime after 100 hours provided the difference between the last measurement and the one preceding it is less than 0.5 %. However, the load shall remain on the pipe for at least 10,000 hours to test against brittle failure.

9.7.9 At no point during the testing shall any crack on the interior or exterior of the pipe wall exceed 0.125 in. for a length of 1 ft or greater. Crack widths greater than 0.125 in. are deemed a failure of the pipe in this test.

NOTE 5—As used in this specification, the 0.125 in. crack is a test criterion for pipe tested in the three-edge-bearing test and is not an indication of failed pipe under installed conditions.

9.7.10 Provided the pipe does not fail within 10,000 hours, the long-term serviceability factor may be established on the basis of the ratio of the final extrapolated (ID_f) and initial (ID_o) inside vertical dimensions of the pipe. This is expressed as:

$$\alpha = ID_f / ID_o \quad (1)$$

where:

α = long-term serviceability factor (unitless),
ID_o = initial inside vertical dimension of the pipe (in.), and
ID_f = final extrapolated inside vertical dimension of the pipe (in.).

9.7.11 Test a minimum of three specimens. Average the results of the tests to determine the long-term serviceability factor.

9.7.12 The α value and its associated test report shall be maintained on file at the production facility.

10. Pipe Proof of Design Testing

10.1 *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.

10.2 *Proof of Design*—When testing for proof of design, the pipe tests shall be conducted in accordance with Test Method C497. Prior to loading, measure the vertical internal diameter at 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 synthetic fiber-reinforced concrete matrix. The tested D_{Ult} value shall be recorded and shall not be less than the D_{Ult} value prescribed in Table 1 for each respective class of pipe.

10.3 *Proof of Bond/Ductility/Toughness/Long-Term Serviceability*—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

TABLE 2

Hours	Measurements taken at Least
0 to 20	Every 1 hour
20 to 40	Every 2 hours
40 to 60	Every 4 hours
60 to 100	Every 8 hours
100 to 600	Every 24 ± 6 hours
600 to 6000	Every 48 ± 10 hours
After 6000	Every week

inside C497. diameter has reduced vertically at either end by at least 2 % of the initial diameter. As a verification of bond, ductility, toughness, and long-term serviceability, the pipe shall be loaded until it reaches D2 $\%_{Reload}$. Ddeflection.$_{Reload}$ is defined Record the peak load (D_P) as follows:

$$D_{Reload} = D_{Service}/\alpha \quad (2)$$

$$D_P = D_{Service}/\alpha \quad (2)$$

where:

D_{Reload} = the load applied after removing the ultimate load from the pipe (lb/ft/ft). D_{Reload} shall exceed the required service load condition by an amount equal to (1/α – 1) multiplied by $D_{Service}$ to ensure the pipe will perform in service over the long-term,
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 condition by an amount equal to (1/α – 1) multiplied by $D_{Service}$ to ensure the pipe will perform in service over the long-term,
$D_{Service}$ = service load strength required by the pipe (lb/ft/ft), and
α = long-term serviceability factor to account for long-term properties of the synthetic fiber in the concrete matrix, as determined in accordance with Section 9.

NOTE 6—This test ensures the fibers have both the anchorage and tensile strength to continue to behave in a ductile, not brittle manner to a performance level sufficient to guarantee the long-term performance of the pipe.pipe throughout the 1 % to 2 % deflection according to typical rigid design assumptions.

10.4 *Establishment of Pipe Strength:*

10.4.1 Three to seven representative specimens, of standard production pipe, shall be tested in accordance with 10.2 and 10.3. The ultimate load (D_{Ult}) shall be recorded. If the reload test has verified that each pipe has attained the $D_{ReloadP}$ test load, use the procedures presented in 10.4.2 and 10.4.3 to compute the $\bar{X}$ and $\bar{X}_s$ for the D_{Ult} test loads.

NOTE 7—It is necessary that samples be selected at random. For guidance, see Practice E105.

10.4.2 Compute the estimated standard deviation, *s*, by Eq 3 or Eq 4, which yield identical values.

$$s = \sqrt{\left[\Sigma\left(X_i - \bar{X}\right)^2\right]/(n - 1)} \quad (3)$$

$$s = \sqrt{\left[\Sigma X_i^2 - (\Sigma X_i)^2/n\right]/(n - 1)} \quad (4)$$

where:

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

10.4.3 Compute the minimum allowable arithmetic mean, $\bar{X}_s$, by Eq 5. In Eq 5, the value of the estimated standard deviation, *s*, shall be as calculated by Eq 3 or Eq 4 or equal to 0.07*L*, whichever is greater.

$$\bar{X}_s = L + S_m \quad (5)$$

where:

L = specification limit (specified D-load), and
S_m = modified standard deviation dependent upon sample size (see Table 3).

TABLE 3

Sample size (*n*)	S_m value
3	1.08s
4	1.09s
5	1.10s
7	1.16s