Designation: C1818 – 15

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., 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.

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, 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
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
D7508/D7508M Specification for Polyolefin Chopped Strands for Use in 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 standard, see Terminology C822.

3.2 *Definitions:*

3.2.1 D_{Reload}—the D_{Service} load divided by the long-term serviceability factor α as determined in accordance with Section 9.

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.

5. Basis of Acceptance

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

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[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 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)
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

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.

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_{Reload} 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_{Service} 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.

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

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. 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 C497. As a verification of bond, ductility, toughness, and long-term serviceability, the pipe shall be loaded until it reaches D_{Reload}. D_{Reload} is defined as follows:

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

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,
$D_{Service}$ = 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.

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_{Reload} 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 $0.07L$, 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).

10.4.4 The pipe shall be deemed acceptable if the arithmetic mean $\bar{X}$ for the D_{Ult} strength values is equal to or greater than $\bar{X}_s$, and all the pipe specimens pass the D_{Reload} requirement

10.5 *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_{Ult} and D_{Reload} values shall be reestablished in accordance with 10.4. Provided there is no change in material or manufacture of the pipe used to establish the pipe class, pipe shall be tested in accordance with Section 11 for quality assurance.

11. Physical Requirements

11.1 The proof of design is as required in accordance with Section 10. The test requirements of this section apply to the quality assurance of pipe production with the pipe being tested to D_{Ult} and D_{Reload} ($D_{Service}$ divided by α).

11.2 *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.

11.3 *External Load Test Strength*—The load to produce the D_{Ult} Load as determined by the three-edge-bearing method

TABLE 3

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

described in the Test Methods C497 shall not be less than that prescribed for D_{Ult} in Table 1 for each respective class of pipe.

11.4 *Proof of Bond/Ductility/Toughness/Long-Term Serviceability*—After the strength test, the pipe shall be immediately unloaded and reloaded in accordance with Test Method C497 to the D_{Reload} level as prescribed in Table 1.

11.5 *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 11.3 and 11.4. 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 8—While cracks may occur in synthetic 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.

11.6 *Retests of Pipe*—If any pipe fails to pass the three-edge bearing test requirements for either the D_{Ult} or D_{Reload}, then three more pipes 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 production run and the pipe shall be accepted if they conform to the requirements of this specification.

11.7 *Absorption*—An annual absorption test shall be performed 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

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

11.9 *Compression Testing of Cylinders:*

11.9.1 *Cylinder Production*—Cylinders shall be prepared in accordance with the Cylinder Strength Test Method of Test Methods C497.

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

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

11.9.3.1 When the compressive strengths of all cylinders tested for a group are equal to or greater than the design synthetic fiber concrete strength, the compressive strength of the synthetic fiber concrete in the group of pipe sections shall be accepted.

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

11.9.3.3 When the compressive strength of the cylinders tested does not conform to the acceptance criteria stated in 11.9.3.1 or 11.9.3.2, the acceptability of the group shall be determined in accordance with the provisions of 11.10.

11.10 *Compression Testing of Cores:*

11.10.1 *Obtaining Cores*—Cores shall be obtained, prepared, and tested in accordance with the Core Strength Test Method of Test Methods C497.

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

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

11.11.1 The compressive strength of the synthetic fiber concrete for each group of pipe sections is acceptable when the synthetic 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 synthetic fiber concrete with no one core less than 75 % of the required strength.

11.11.2 If the compressive strength of the three cores does not meet the requirements of 11.11.1, 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 11.3. If all three pipe sections meet the D_{Ult} and D_{Reload} requirements the remainder of the group shall be acceptable. If any one of the three pipes does not meet the D_{Ult} and D_{Reload} requirements 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.

12. Dimensions and Permissible Variations

12.1 *Standard Diameters*—Pipe shall be manufactured in the standard inside diameters listed in Table 4. The manufacturer shall request approval by the purchaser for larger sizes.

12.2 *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 27 in. and larger shall not vary by more than 1 % of the design diameter or ±3⁄8-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 11.

TABLE 4 Standard Designated Inside Diameter, in.

12	24	36
15	27	42
18	30	48
21	33	

12.3 *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 10.

12.4 *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

12.5 *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.

13. Repairs

13.1 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.

14. Inspection

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

15. Rejection

15.1 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:

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

15.1.2 Defects that indicate proportioning, mixing, and molding, not in compliance with 7.6.1, or surface defects indicating honeycombed or open texture that would adversely affect the function of the pipe.

15.1.3 The ends of the pipe are not normal to the walls and center line of the pipe, within the limits of variations given in 12.4 and 12.5.

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

15.2 Exposure of synthetic fibers is not a cause for rejection.

16. Disposition of a Rejected Lot

16.1 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 $D_{Service}$ strength for the lot, or develop an acceptable disposition. The manufacturer shall bear all expenses incurred by the procedure.

17. Certification

17.1 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.

18. Product Marking

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

18.1.1 ASTM Designation,

18.1.2 The pipe size,

18.1.3 The pipe class or minimum Service Load, whichever is specified, and specification designation,

18.1.4 The date of manufacture,

18.1.5 Name or trademark of the manufacturer, and

18.1.6 Identification of plant.

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

19. Keywords

19.1 circular pipe; D-load; sewer pipe; storm drains; SynFRCP; synthetic fibers; three edge bearing strength

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLE CALCULATION

X1.1 As required by 10.2 and 10.3, the strength verification of a 24-in. designated inside diameter pipe will be determined in accordance with 10.4. The service load strength, $D_{Service}$ is specified as 1350 lbf/linear ft per foot of designated diameter (Class III Pipe).

X1.2 Therefore, the required ultimate strength D_{Ult} is determined as 1350 × 1.5 = 2025 lbf/linear ft per foot of designated inside diameter.

X1.3 The α factor has been supplied by a third-party independent lab as α = 0.90. Therefore, the D_{Reload} test strength is determined as 1350/0.90 = 1500 lbf/linear ft per foot of designated inside diameter.

X1.4 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 ft long).

X1.5 Test the pipe to D_{Ult}. Record the observed D_{Ult} values of X_i in pounds-force: 38000, 32400, 37300, 35200, and 38900.

X1.6 Test the same pipes to D_{Reload} and verify that the D_{Reload} test strength of 1500 lbf/linear ft per foot is attained for each pipe.

X1.7 Since in this example X_i is in pounds-force, convert the specification limit L_{Ult} (Ultimate strength D-load) to pounds by multiplying the D-load times the designated inside diameter in feet by the pipe length in feet, or

$$L_{Ult} = 2025\left(\frac{24}{12}\right)\cdot 8 \quad \text{(X1.1)}$$

$$L_{Ult} = 32400 \text{ lbs}$$

X1.8 Compute the required minimum allowable value in accordance with the acceptability criteria of 10.4.

X1.9 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.

X1.10 Calculate the values for $\bar{X}$ as follows:

XU_i =	$(XU_i)^2$ =
380	144400
324	104976
373	139129
352	123904
389	151321
$\Sigma XU_i = 1818$	$\Sigma XU_i^2 = 663730$

$$(\Sigma X U_i)^2 = (1818)^2 \quad \text{(X1.2)}$$

$$= 3305124$$

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

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

$$\bar{X} \text{ of } D_{Ult} = (1818/5) \times 100$$

$$\bar{X} \text{ of } D_{Ult} = 36360 \text{ lbs}$$

X1.11 The standard deviation, s, shall be computed by either Eq 3 or Eq 4. Since Eq 4 is a simpler form for computation, this will be used.

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

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

$$S_{Ult} = \sqrt{676}$$

$$S_{Ult} = 26$$

X1.12 Multiply by 100 to obtain total pounds-force:

$$S_{Ult} = 26 \times 100 \quad \text{(X1.5)}$$

$$S_{Ult} = 2600 \text{ lbs}$$

The required minimum allowable arithmetic mean X_s is computed by Eq 5, using $S_m = 1.10$ s for five samples:

$$\bar{X}_s \text{ of } D_{Ult} = L_{Ult} + 1.10 \ S_{Ult} \quad \text{(X1.6)}$$

$$\bar{X}_s \text{ of } D_{Ult} = 32400 + 1.10 \times 2600$$

$$\bar{X}_s \ D_{Ult} = 35260 \text{ lbs}$$

Since the actual $\bar{X}$ of 36,360 lbf for D_{Ult} is greater than the required minimum allowable $\bar{X}_s$ of 35,260 lbf for D_{Ult}, the pipe material and manufacturing process result in a pipe that is verified to meet the Class III strength designation.

X1.13 ASTM STP 15D is a valuable source of information regarding statistical procedures and simplified computational methods.

X2. LOAD DEFORMATION PROPERTIES OF SYNTHETIC FIBER REINFORCED CONCRETE PIPE

X2.1 When loaded to its ultimate capacity, synthetic fiber reinforced concrete pipe will have a larger drop in load capacity than a standard reinforced concrete pipe of similar ultimate load capacity.

X2.2 Standard reinforced concrete pipe initially develops cracks when the concrete's modulus of rupture is exceeded, which result in the reinforcing steel carrying the load on the tension face of the pipe wall. The steel strength and its development length within the pipe wall give the pipe the capability to carry additional load until it reaches ultimate, at which time the reinforcing steel has reached its capability to carry anymore tension load.

X2.3 The fibers in synthetic fiber reinforced concrete pipe enhance the modulus of rupture of the concrete-fiber matrix and result in extending the pipe strength prior to crack above what it might otherwise be. However, once the pipe cracks and the fibers are the primary elements carrying the forces in the tensile face of the pipe wall, the loss in pipe strength is in excess of what occurs with a standard RCP Pipe. However, the concrete-fiber matrix allows for better distribution of the concrete cracking, resulting in more ductility in the Syn-FRCP than would otherwise be observed in regular RCP (see Fig. X2.1).

X2.4 The testing regime in this standard requires that the Syn-FRCP be tested to ultimate to ensure that the fiber reinforced pipe does in fact maintain some structural stability without total collapse. The pipe is then reloaded to ensure that some semblance of bond between the fibers and concrete are maintained.

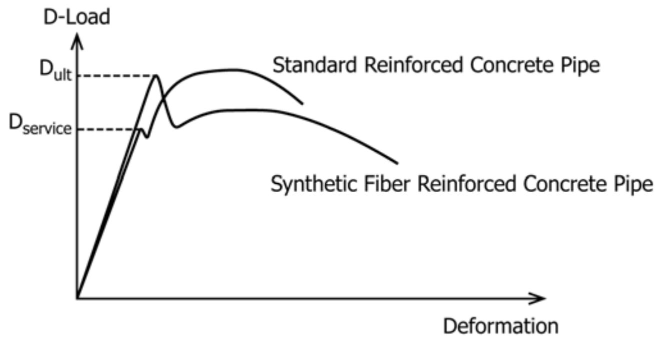

FIG. X2.1 Schematic Representation of Synthetic Fiber Concrete Pipe Versus Reinforced Steel Concrete Pipe

X2.5 Depending upon their chemical constituents, synthetic fibers will have some level of time-dependent material properties. To account for this, a testing requirement for the long-term serviceability of the concrete-fiber matrix is incorporated into this standard, and the results are then incorporated into the D_{Reload} requirements.