Designation: C 985 – 04$^{\epsilon 1}$

Standard Specification for Nonreinforced Concrete Specified Strength Culvert, Storm Drain, and Sewer Pipe[1]

This standard is issued under the fixed designation C 985; 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.

ϵ^1 NOTE—Editorial changes were made throughout in March 2005.

1. Scope

1.1 This specification covers nonreinforced concrete pipe designed for specified strengths and intended to be used for the conveyance of sewage, industrial wastes, and storm water and for the construction of culverts.

1.2 A complete companion to Specification C 985 has been developed, C 985M; therefore, no metric equivalents are presented in this specification.

NOTE 1—This specification is a manufacturing and purchase specification only and does not include requirements for bedding, backfill, or the relationship between field load conditions and the designated strength of the pipe. However, experience has shown that the successful performance of this product depends upon the proper selection of the pipe strength, type of bedding and backfill, and care that the installation conforms to the construction specifications. The owner of the concrete pipe specified herein is cautioned that he must correlate the field requirements with the pipe strength specified and provide inspection at the construction site.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 82 Specification for Steel Wire, Plain, for Concrete Reinforcement

A 185 Specification for Steel Welded Wire Reinforcement, Plain, for Concrete

A 496 Specification for Steel Wire, Deformed, for Concrete Reinforcement

A 497 Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete

A 615/A 615M Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

C 33 Specification for Concrete Aggregates

C 150 Specification for Portland Cement

C 497 Test Methods for Concrete Pipe, Manhole Sections, or Tile

C 595 Specification for Blended Hydraulic Cements

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolon for Use as a Mineral Admixture in Concrete

C 822 Terminology Relating to Concrete Pipe and Related Products

C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars

C 1116 Specification for Fiber-Reinforced Concrete and Shotcrete

E 105 Practice for Probability Sampling of Materials

3. Terminology

3.1 *Definitions*—For definitions of terms relating to concrete pipe, see Terminology C 822.

4. Basis of Acceptance

4.1 The acceptability of the pipe design shall be determined in accordance with Section 9. After the pipe design has been accepted, or if the pipe design has been accepted previously in accordance with Section 9, production pipe shall be accepted in accordance with 4.2.

4.2 *Acceptance on the Basis of Pipe Load and Material Tests and Inspection of Manufactured Pipe for Defects*—Determine in accordance with Sections 5, 6, 8, and 11.

NOTE 2—It is necessary that samples be selected at random. For guidance, see Practice E 105.

4.3 *Age for Acceptance*—Pipe shall be considered ready for acceptance when it conforms to the requirements as indicated by the specified tests.

5. Design and Manufacturing Data

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

5.1.1 Basis of acceptance and supporting data,

5.1.2 Designated pipe strength,

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

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

5.1.4 Admixtures,

5.1.5 Manufacturing and curing process, and

5.1.6 *Handling Reinforcement*:

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

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

6. Materials and Manufacture

6.1 *Materials*:

6.1.1 *Concrete*—The concrete shall consist of cementitious materials, mineral aggregates, and water.

6.1.2 *Cementitious Materials*:

6.1.2.1 *Cement*—Cement shall conform to the requirements for portland cement of Specification C 150 or shall be portland blast-furnace slag cement or portland-pozzolan cement conforming to the requirements of Specification C 595, except that the pozzolan constituent in the Type IP portland pozzolan cement shall be fly ash.

6.1.2.2 *Fly Ash*—Fly ash shall conform to the requirements of Specification C 618, Class F or Class C.

6.1.2.3 *Ground Granulated Blast-Furnace Slag (GGBFS)*—GGBFS shall conform to the requirements of Grade 100 or 120 of Specification C 989.

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

(1) Portland cement only,

(2) Portland blast furnace slag cement only,

(3) Slag modified portland cement only,

(4) Portland pozzolan cement only,

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

(6) A combination or portland cement and ground granulated blast-furnace slag.

(7) A combination of portland cement, ground granulated blast furnace slag (not to exceed 25% of the total cementitious weight), and fly ash (not to exceed 25% of the total cementitious weight).

6.1.3 *Aggregates*—Aggregates shall conform to the requirements of Specification C 33, except that the requirement for gradation shall not apply.

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

6.1.5 *Steel Reinforcement*—Reinforcement shall consist of wire conforming to Specification A 82, or Specification A 496, or of wire fabric conforming to Specification A 185, or Specification A 497, or of bars of Grade 40 steel conforming to Specification A 615/A 615M.

6.2 *Manufacture*:

6.2.1 *Mixture*—The aggregates shall be sized, graded, proportioned, and mixed with cementitious materials, water, and admixtures, if any, to produce a homogeneous concrete mixture of such quality that the pipe will conform to the design and test requirements of this specification.

6.2.2 *Handling Reinforcement*—Circumferential handling reinforcement shall be provided in all pipe larger than 36 in. in diameter.

6.2.2.1 *Placement*—Where one line of circular reinforcement is used, it shall be placed between 30 and 50 % of the wall thickness from the inside surface. Where two lines of circular reinforcement are used, each line shall be so placed that the protective covering over the circumferential reinforcement in the wall of the section shall be 1 in.

6.2.2.2 *Splices*—If the splices are not welded, the reinforcement shall be lapped not less than 20 diameters for deformed bars, and 40 diameters for plain bars and cold-drawn wire. When splices are welded and are not lapped to the minimum requirements above, there shall be a minimum lap of 2 in. and pull tests of representative specimens shall develop at least 50 % of the minimum specified strength of the steel.

6.2.2.3 *Spacing*—Handling reinforcements shall be individual hoops or shall be formed into a cage or cages. It shall be distributed along the length of the pipe section, or one half of the minimum reinforcement shall be allowed to be placed in each of the extreme quarters of the length of an 8-ft or less pipe section, or one third of the minimum reinforcement shall be allowed to be placed in each third of the length of a longer than 8-ft pipe section. Additionally, at least 75 % of the minimum area shall be located not less than one fifteenth of the length of the pipe section from any portion of the joint.

6.2.2.4 *Area*—The minimum area of circumferential handling reinforcement shall be equal to $0.00003\ (D + t)^2$ in square in. per ft of pipe, where "D" equals the designated diameter in inches and "t" equals the wall thickness in inches.

6.2.2.5 *Special Designs*— The manufacturer shall be allowed to submit special designs to the owner for approval. Approval shall be based on structural calculations or on load tests. The minimum ultimate three-edge bearing load shall be equal to the weight of the pipe and shall be sustained by the pipe after cracking at the top, bottom and sides the full length of the pipe. The pipe shall also meet the strength requirements of Section 7, and Section 10 or 11, or both.

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

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

6.3 *Synthetic Fibers*—Collated fibrillated virgin polypropylene fibers shall be allowed to be used, at the manufacturer's option, in concrete pipe as a nonstructural manufacturing material. Only Type III synthetic fibers designed and manufactured specifically for use in concrete and conforming to the requirements of Specification C 1116 shall be accepted.

7. Physical Properties

7.1 *Pipe Strength*— Pipe strength shall be either a designated strength or a cracking strength. The designated strength is that specified as the minimum load required to produce the cracking strength when tested in three-edge bearing in accordance with Test Methods C 497. The cracking strength is the actual maximum load observed in the three-edge bearing test,

and shall be assumed to have been reached when any continuous visible crack caused by the test load exceeds 1 ft in length measured parallel to the longitudinal axis of the pipe.

NOTE 3—For pipe made without handling steel, the designated strength is the minimum load required to produce the ordinary nonreinforced pipe load at ultimate failure. For safety reasons, DO NOT look for a visible crack during a three-edge bearing test of pipe without reinforcing.

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

7.3 *Test Methods*— The tests for crushing strength shall be made in accordance with Test Methods C 497. When alternative methods of load testing are specified, tests shall be made in accordance with the alternative requirements.

8. Dimensions and Permissible Variations

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

TABLE 1 Standard Designated Internal Diameters, in.

4	24	36
6	27	42
8	30	48
10	33	54
12		60
15		
18		
21		

NOTE 4—Diameters other than those shown in Table 1 may be available. When such sizes are required, the owner should contact the manufacturers in the project area.

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

8.2.1 *Diameter Tolerances*—The internal diameter shall not vary from the designated diameter by more than ±3⁄16 in. for pipe 12 in. in diameter; by more than ±¼ in. for pipe 15 or 18 in. in diameter; by more than ±5⁄16 in. for pipe 21 in. in diameter; by more than ±⅜ in. for pipe 24 in. to 36 in. in diameter; and by more than ±1 % for pipe larger than 36 in. in diameter.

8.2.2 *Handling Reinforcement Placement Tolerances*—The maximum variation in the nominal position of the reinforcement shall be ±10 % of the wall thickness or ±⅝ in., whichever is greater. Pipe having variations in the position of the reinforcement exceeding those specified above shall be accepted if the three-edge bearing strength requirements are met by a representative sample. In no case, however, shall the cover over the circumferential reinforcement be less than ½ in.

8.2.3 *Laying Length Tolerances*—The length of any section of pipe shall not vary more than ½ in. from a specified or designated design length. The length of two opposite sides of any section of pipe shall not vary more than ¼ in. or 2 % of the designated diameter, whichever is larger.

8.2.4 *Wall Thickness Tolerances*—The wall thickness shall not be less than the thickness specified under 5.1.3 by more than 5 % or ⅛ in. for pipe 12 to 24 in. in diameter, whichever is greater; and by more than 5 % or 3⁄16 in. for pipe larger than 24 in. in diameter, whichever is greater. Localized variations in wall thickness exceeding those specified above shall be accepted if the physical test requirements specified herein are met. A wall thickness greater than that required by the design is not a cause for rejection, except that such pipe shall not be used for tests required in Section 4.

8.2.5 *Straightness Tolerances*—Pipe intended to be straight shall not vary in alignment more than ⅛ in./ft of length.

9. Acceptance of Design

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

9.1.1 Compute the estimated standard deviation, s, by Eq 1 or Eq 2, that yield identical values, as follows:

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

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

where:

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

9.1.2 Compute the minimum allowable arithmetic mean, $\bar{X}_s$, by Eq 3. In Eq 3 the value of the estimated standard deviation, s, shall be calculated by Eq 1 or Eq 2 or equal to 0.01 L, whichever is greater.

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

where:

L = Specification limit (designated strength).

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

9.2 *Alternative Acceptance Method*—The manufacturer shall be allowed to request approval of designs based on empirical evaluations of the strength of the pipe including, but not limited to, designs based on interpolation between designs approved in accordance with 10.1, or designs evaluated on the basis of tests other than the three-edge bearing test method. Acceptance of design tests need not be performed for each contract or order.

10. Acceptance of Pipe by Load Testing

10.1 *Lot Sampling*— The owner shall randomly select from the lot a sample of the size listed in Table 2.

TABLE 2 Sample Sizes

Lot Size	Sample Size	Equation	Equation No.
0 to 300	3	$\bar{X}_s = L + 1.08\,s$	(4)
310 to 500	4	$\bar{X}_s = L + 1.09\,s$	(5)
501 to 800	5	$\bar{X}_s = L + 1.10\,s$	(6)
801 to 1 300	7	$\bar{X}_s = L + 1.16\,s$	(7)

10.2 *Designated Strength Testing*:

10.2.1 At the manufacturer's option, each specimen of the sample shall be tested to the designated strength. If all specimens reach the designated strength, without visible cracks exceeding one foot in length, the lot shall be accepted.

10.2.2 If any of the test specimens do not reach the designated strength, the lot shall be resampled and tested in accordance with 11.3.

10.2.3 After testing as prescribed in the preceding sections, any of the test specimens that were not cracked, or otherwise structurally damaged, shall be allowed to be included in the lot for shipment.

10.3 *Cracking Strength Testing*:

10.3.1 Test each specimen to the cracking strength. When all specimen test strengths are equal to or greater than that specified, the lot shall be accepted.

10.3.2 When one or more specimen test strengths are less than that specified, the values for $\bar{X}$ and s shall be computed and substituted into the applicable equation given in Table 2. When the arithmetic mean $\bar{X}$ is equal to or greater than the computed value of $\bar{X}_s$, the lot shall be acceptable.

10.3.3 When the arithmetic mean $\bar{X}$ is less than the computed values of $\bar{X}s$, the lot shall be rejected for that strength.

10.4 *Use of Design Test Data*—When the pipe tested in Section 10 were selected at random from a production lot, the test data shall be allowed to be used in the acceptance analysis of that lot.

11. Inspection

11.1 The quality of materials, process of manufacture, and the finished pipe shall be subject to inspection by the owner. Pipe that is observed to have cracks or other defects in form or dimensions in excess of the limits permitted in this specification shall be discarded and replaced.

12. Rejection

12.1 Pipe shall be subject to rejection for 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:

12.1.1 Fractures or cracks passing through the wall or joints, except that a single crack not exceeding 2 in. in length at either end of a pipe or a single fracture or spall in the joints not exceeding 3 in. around the circumference of the pipe nor 2 in. in length into joint shall not be considered cause for rejection unless these defects exist in more than 5 % of the lot.

12.1.2 Defects that indicate mixing and molding not in compliance with 6.2.1.

12.1.3 The ends of the pipe are not normal to the walls and center line of the pipe, within the limits of variations given in 8.2.3.

12.1.4 Cracks sufficient to impair the strength, durability, or serviceability of the pipe.

12.1.5 Surface defects that indicate honeycombed or open texture that would adversely affect the function of the pipe.

13. Disposition of a Rejected Lot

13.1 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 to by the manufacturer and the owner. The procedure may demonstrate improvement in the lot, statistically calculate a reduced strength for the lot, or develop an acceptable disposition. The manufacturer shall bear all expenses incurred by the procedure.

14. Repairs

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

15. Certification

15.1 When agreed upon in writing by the owner and the manufacturer, a certification shall be made the basis of acceptance. This shall consist of a copy of the manufacturer's test report or a statement by the manufacturer, accompanied by a copy of the test results, that the pipe has been sampled, tested, and inspected in accordance with the provisions of Section 4. Each certification so furnished shall be signed by the manufacturer or an authorized agent.

16. Product Marking

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

16.1.1 The designated pipe strength in lbf per linear ft and specification designation,

16.1.2 The date of manufacture,

16.1.3 The name or trademark of the manufacturer, and

16.1.4 Identification of the plant.

16.2 Marking shall be indented on the pipe section or painted thereon with waterproof paint.

17. Keywords

17.1 concrete pipe—nonreinforced; culvert; sewer pipe; storm drain; three edge bearing strength

APPENDIX

(Nonmandatory Information)

X1. ACCEPTANCE OF PIPE BY LOAD TESTING

X1.1 Given

X1.1.1 The acceptability of 600 sections of 60-in. inside diameter pipe will be determined in accordance with Section 11. The designated pipe strength is 4000 lbf/linear ft. With a wall thickness of 6.75 in., the pipe weighs 1500 lbf/linear ft. For proof of design specimens and production lots, the pipe is manufactured in 8-ft lengths.

X1.2 Example 1

X1.2.1 *Sample Selection*—From the lot, randomly select a sample of five specimens ($n = 5$) in accordance with Table 2.

X1.2.2 *Test Results*— Test the specimens, and record the observed values of the cracking strengths, X_i: 56 000, 49 500, 52 000, 51 500, and 48 000 lbf.

X1.2.3 *Specification Limit*—Since X_i is in lbf, convert the specification limit (designated strength), L, to lbf:

$$L = 4000 \times 8 = 32\ 000 \text{ lbf}$$

X1.2.4 *Acceptability*— Since all of the observed values of cracking strength are greater than the specification limit ($L = 32\ 000$), the lot of pipe is acceptable.

X1.3 Example 2

X1.3.1 *Test Results*— If in X1.2.2 the observed value of 56 000 lbf had been 31 000 lbf, it would be less than the specification limit ($L = 32\ 000$), and acceptability of the lot must be determined in accordance with Section 11.

X1.3.2 *Calculation of* $\bar{X}$—Calculate the arithmetic mean, $\bar{X}$, of the observed cracking strength values:

X_i	X_i^2
310	96 100
495	245 025
520	270 400
515	265 225
480	230 400
$\Sigma X_i = 2320$	$\Sigma X_i^2 = 1\ 107\ 150$

NOTE X1.1—The observed values of cracking strengths were divided by 100 to simplify computations in accordance with the recommendation of Section 25, *ASTM STP 15C*.[3] The effect is to reduce the size of numbers to enable the use of a desk calculator.

$$(\Sigma X_i)^2 = (2320)^2 = 5\ 382\ 400$$

$$\bar{X} = (\Sigma X_i/n) \times 100$$

$$\bar{X} = (2320/5) \times 100$$

$$\bar{X} = 46\ 400 \text{ lbf}$$

X1.3.3 *Standard Deviation*—Calculate the standard deviation, s, using Eq X1.1, which is in a simpler form for calculations:

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

$$s = \sqrt{[1\ 107\ 150 - 5\ 382\ 400/5]/(5-1)}$$

$$s = 87.6$$

Multiply s by 100 to obtain lbf:

$$s = 87.6 \times 100 = 8\ 760 \text{ lbf}$$

X1.3.4 *Calculation of* $\bar{X}_s$—Calculate the minimum allowable arithmetic mean, cracking strength, $\bar{X}_s$, by Eq X1.2:

$$\bar{X}_s = L + 1.10s \quad \text{(X1.2)}$$

$$\bar{X}_s = 32\ 000 + 1.10 \times 8\ 760$$

$$\bar{X}_s = 41\ 600 \text{ lbf}$$

X1.3.5 *Acceptability*—Since the $\bar{X}$ (46 400) is greater than $\bar{X}_s$ (41 600), the lot of pipe is acceptable.

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