Designation: C 76 – 08a

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

This standard is issued under the fixed designation C 76; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

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

1.2 This specification is the inch-pound companion to Specification C 76M; therefore, no SI equivalents are presented in this specification. Reinforced concrete pipe that conform to the requirements of C 76M, are acceptable under this Specification C 76 unless prohibited by the Owner.

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 condition and the strength classification of pipe. However, experience has shown that the successful performance of this product depends upon the proper selection of the class of pipe, type of bedding and backfill, and care that installation conforms to the construction specifications. The owner of the reinforced concrete pipe specified herein is cautioned that he must correlate the field requirements with the class of pipe specified and provide inspection at the construction site.

NOTE 2—Attention is called to the specification for reinforced concrete D-load culvert, storm drain, and sewer pipe (Specification C 655).

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 36/A 36M Specification for Carbon Structural Steel
A 82/A 82M Specification for Steel Wire, Plain, for Concrete Reinforcement
A 185/A 185M Specification for Steel Welded Wire Reinforcement, Plain, for Concrete
A 496/A 496M Specification for Steel Wire, Deformed, for Concrete Reinforcement
A 497/A 497M Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete
A 615/A 615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
A 706/A 706M Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
C 33 Specification for Concrete Aggregates
C 76M Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe [Metric]
C 150 Specification for Portland Cement
C 260 Specification for Air-Entraining Admixtures for Concrete
C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete
C 494/C 494M Specification for Chemical Admixtures for Concrete
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 Pozzolan for Use in Concrete
C 655 Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe
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 1017/C 1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete
C 1116 Specification for Fiber-Reinforced Concrete and Shotcrete

3. Terminology

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

4. Classification

4.1 Pipe manufactured in accordance with this specification shall be of five classes identified as Class I, Class II, Class III, Class IV, and Class V. The corresponding strength requirements are prescribed in Tables 1-5.

[1] This specification 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 Design Requirements for Class I Reinforced Concrete Pipe[A]

NOTE 1—See Section 5 for basis of acceptance specified by the owner.

The strength test requirements in pounds-force per linear foot of pipe under the three-edge-bearing method shall be either the D-load (test load expressed in pounds-force per linear foot per foot of diameter) to produce a 0.01-in. crack, or the D-loads to produce the 0.01-in. crack and the ultimate load as specified below, multiplied by the internal diameter of the pipe in feet.

D-load to produce a 0.01-in. crack	800
D-load to produce the ultimate load	1200

Internal Designated Diameter, in.	Reinforcement, in.²/linear ft of pipe wall								
	Wall A					Wall B			
	Concrete Strength, 4000 psi					Concrete Strength, 4000 psi			
	Wall Thickness, in.	Circular Reinforcement[B]		Elliptical Reinforcement[C]		Wall Thickness, in.	Circular Reinforcement[B]		Elliptical Reinforcement[C]	
		Inner Cage	Outer Cage				Inner Cage	Outer Cage		
60	5	0.25	0.15	0.28		6	0.21	0.13	0.23	
66	5½	0.30	0.18	0.33		6½	0.25	0.15	0.28	
72	6	0.35	0.21	0.39		7	0.29	0.17	0.32	
78	6½	0.40	0.24	0.44		7½	0.32	0.19	0.36	
84	7	0.45	0.27	0.50		8	0.37	0.22	0.41	
90	7½	0.49	0.29	0.54		8½	0.41	0.25	0.46	
96	8	0.54	0.32	0.60		9	0.46	0.28	0.51	
	Concrete Strength, 5000 psi									
102	8½	0.63	0.38	Inner Circular	0.25	9½	0.54	0.32	Inner Circular	0.22
				Plus Elliptical	0.38				Plus Elliptical	0.32
108	9	0.68	0.41	Inner Circular	0.27	10	0.61	0.37	Inner Circular	0.24
				Plus Elliptical	0.41				Plus Elliptical	0.37
114	[A]	...	...	...	...	[A]	...	...	...	...
120	[A]	...	...	...	...	[A]	...	...	...	...
126	[A]	...	...	...	...	[A]	...	...	...	...
132	[A]	...	...	...	...	[A]	...	...	...	...
138	[A]	...	...	...	...	[A]	...	...	...	...
144	[A]	...	...	...	...	[A]	...	...	...	...

[A] For modified or special designs see 7.2 or with the permission of the owner utilize the provisions of Specification C 655. Steel areas may be interpolated between those shown for variations in diameter, loading, or wall thickness. Pipe over 96 in. in diameter shall have two circular cages or an inner circular plus one elliptical cage.

[B] As an alternative to designs requiring both inner and outer circular cages the reinforcement may be positioned and proportioned in either of the following manners:

An inner circular cage plus an elliptical cage such that the area of the elliptical cage shall not be less than that specified for the outer cage in the table and the total area of the inner circular cage plus the elliptical cage shall not be less than that specified for the inner cage in the table,

An inner and outer cage plus quadrant mats in accordance with Fig. 1, or

An inner and outer cage plus an elliptical cage in accordance with Fig. 2.

[C] Elliptical and quadrant steel must be held in place by means of holding rods, chairs, or other positive means throughout the entire casting operation.

5. Basis of Acceptance

5.1 Unless otherwise designated by the owner at the time of, or before placing an order, there are two separate and alternative bases of acceptance. Independent of the method of acceptance, the pipe shall be designed to meet both the 0.01-in. crack and ultimate strength requirements specified in Tables 1-5.

5.1.1 *Acceptance on the Basis of Plant Load-Bearing Tests, Material Tests, and Inspection of Manufactured Pipe for Visual Defects and Imperfections*—Acceptability of the pipe in all diameters and classes produced in accordance with 7.1 or 7.2 shall be determined by the results of the three-edge bearing tests as defined in 11.3.1; by such material tests as are required in 6.2, 6.3, 6.5, and 6.6; by an absorption test of the concrete from the wall of the pipe for each mix design that is used on an order; and by visual inspection of the finished pipe to determine its conformance with the accepted design and its freedom from defects.

5.1.2 *Acceptance on the Basis of Material Tests and Inspection of Manufactured Pipe for Defects and Imperfections*—Acceptability of the pipe in all diameters and classes produced in accordance with 7.1 or 7.2 shall be determined by the results of such material tests as are required in 6.2, 6.3, 6.5, and 6.6; by crushing tests on concrete cores or cured concrete cylinders; by an absorption test of the concrete from the wall of the pipe for each mix design that is used on an order; and by inspection of the finished pipe including amount and placement of reinforcement to determine its conformance with the accepted design and its freedom from defects.

5.1.3 When agreed upon by the owner and manufacturer, any portion or any combination of the tests itemized in 5.1.1 or 5.1.2 may form the basis of acceptance.

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

6. Materials

6.1 The aggregate shall be so sized, graded, proportioned, and mixed with such proportions of Portland cement, blended hydraulic cement, or Portland cement and supplementary cementing materials, or admixtures, if used, or a combination thereof, and water to produce a homogenous concrete mixture

TABLE 2 Design Requirements for Class II Reinforced Concrete Pipe[A]

NOTE 1—See Section 5 for basis of acceptance specified by the owner.

The strength test requirements in pounds-force per linear foot of pipe under the three-edge-bearing method shall be either the D-load (test load expressed in pounds-force per linear foot per foot of diameter) to produce a 0.01-in. crack, or the D-loads to produce the 0.01-in. crack and the ultimate load as specified below, multiplied by the internal diameter of the pipe in feet.

D-load to produce a 0.01-in. crack	1000
D-load to produce the ultimate load	1500

Internal Designated Diameter, in.	Reinforcement, in.²/linear ft of pipe wall											
	Wall A				Wall B				Wall C			
	Concrete Strength, 4000 psi				Concrete Strength, 4000 psi				Concrete Strength, 4000 psi			
	Wall Thickness, in.	Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]	Wall Thickness, in.	Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]	Wall Thickness, in.	Circular Reinforcement[C] Inner Cage	Circular Reinforcement[C] Outer Cage	Elliptical Reinforcement[D]
12	1¾	0.07[B]	. . .	. . .	2	0.07[B]	. . .	. . .	2¾	0.07[B]	. . .	. . .
15	1⅞	0.07[B]	. . .	. . .	2¼	0.07[B]	. . .	. . .	3	0.07[B]	. . .	. . .
18	2	0.07[B]	. . .	0.07[B]	2½	0.07[B]	. . .	0.07[B]	3¼	0.07[B]	. . .	0.07[B]
21	2¼	0.12	. . .	0.10	2¾	0.07[B]	. . .	0.07[B]	3½	0.07[B]	. . .	0.07[B]
24	2½	0.13	. . .	0.11	3	0.07[B]	. . .	0.07[B]	3¾	0.07[B]	. . .	0.07[B]
27	2⅝	0.15	. . .	0.13	3¼	0.13	. . .	0.11	4	0.07[B]	. . .	0.07[B]
30	2¾	0.15	. . .	0.14	3½	0.14	. . .	0.12	4¼	0.07[B]	. . .	0.07[B]
33	2⅞	0.16	. . .	0.15	3¾	0.15	. . .	0.13	4½	0.07[B]	. . .	0.07[B]
36	3	0.14	0.08	0.15	4[E]	0.12	0.07	0.13	4¾[E]	0.07	0.07	0.08
42	3½	0.16	0.10	0.18	4½	0.15	0.09	0.17	5¼	0.10	0.07	0.11
48	4	0.21	0.13	0.23	5	0.18	0.11	0.20	5¾	0.14	0.08	0.15
54	4½	0.25	0.15	0.28	5½	0.22	0.13	0.24	6¼	0.17	0.10	0.19
60	5	0.30	0.18	0.33	6	0.25	0.15	0.28	6¾	0.22	0.13	0.24
66	5½	0.35	0.21	0.39	6½	0.31	0.19	0.34	7¼	0.25	0.15	0.28
72	6	0.41	0.25	0.45	7	0.35	0.21	0.39	7¾	0.30	0.18	0.33
78	6½	0.46	0.28	0.51	7½	0.40	0.24	0.44	8¼	0.35	0.21	0.39
84	7	0.51	0.31	0.57	8	0.46	0.28	0.51	8¾	0.41	0.25	0.46
90	7½	0.57	0.34	0.63	8½	0.51	0.31	0.57	9¼	0.48	0.29	0.53
96	8	0.62	0.37	0.69	9	0.57	0.34	0.63	9¾	0.55	0.33	0.61
	Concrete Strength, 5000 psi											
102	8½	0.76	0.46	Inner Circular 0.30 Plus Elliptical 0.46	9½	0.68	0.41	Inner Circular 0.27 Plus Elliptical 0.41	10¼	0.62	0.37	Inner Circular 0.25 Plus Elliptical 0.37
108	9	0.85	0.51	Inner Circular 0.34 Plus Elliptical 0.51	10	0.76	0.46	Inner Circular 0.30 Plus Elliptical 0.46	10¾	0.70	0.42	Inner Circular 0.28 Plus Elliptical 0.42
114	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .
120	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .
126	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .
132	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .
138	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .
144	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .	[A]	. . .	. . .	. . . . .

[A] For modified or special designs see 7.2 or with the permission of the owner utilize the provisions of Specification C 655. Steel areas may be interpolated between those shown for variations in diameter, loading, or wall thickness. Pipe over 96 in. in diameter shall have two circular cages or an inner circular plus one elliptical cage.

[B] For these classes and sizes, the minimum practical steel reinforcement is specified. The specified ultimate strength of non-reinforced pipe is greater than the minimum specified strength for the equivalent diameters.

[C] As an alternative to designs requiring both inner and outer circular cages the reinforcement may be positioned and proportioned in either of the following manners:

An inner circular cage plus an elliptical cage such that the area of the elliptical cage shall not be less than that specified for the outer cage in the table and the total area of the inner circular cage plus the elliptical cage shall not be less than that specified for the inner cage in the table,

An inner and outer cage plus quadrant mats in accordance with Fig. 1 , or

An inner and outer cage plus an elliptical cage in accordance with Fig. 2.

[D] Elliptical and quadrant steel must be held in place by means of holding rods, chairs, or other positive means throughout the entire casting operation.

[E] As an alternative, single cage reinforcement may be used. The reinforcement area in square in. per linear foot shall be 0.20 for wall B and 0.16 for wall C.

of such quality that the pipe will conform to the test and design requirements of the specification. In no case, however, shall the proportion of Portland cement, blended hydraulic cement, or a combination of Portland cement and supplementary cementing materials be less than 470 lb/yd^3.

6.2 *Cementitious materials*:

6.2.1 *Cement*—Cement shall conform to the requirements of Specification C 150, or shall be portland blast-furnace slag cement, or slag modified portland 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.

TABLE 3 Design Requirements for Class III Reinforced Concrete Pipe[A]

NOTE 1—See Section 5 for basis of acceptance specified by the owner.

The strength test requirements in pounds-force per linear foot of pipe under the three-edge-bearing method shall be either the D-load (test load expressed in pounds-force per linear foot per foot of diameter) to produce a 0.01-in. crack, or the D-loads to produce the 0.01-in. crack and the ultimate load as specified below, multiplied by the internal diameter of the pipe in feet.

D-load to produce a 0.01-in. crack	1350
D-load to produce the ultimate load	2000

Internal Designated Diameter, in.	Reinforcement, in.²/linear ft of pipe wall											
	Wall A				Wall B				Wall C			
	Concrete Strength, 4000 psi				Concrete Strength, 4000 psi				Concrete Strength, 4000 psi			
	Wall Thicknesses, in.	Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]	Wall Thicknesses, in.	Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]	Wall Thicknesses, in.	Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]
12	1¾	0.07[D]	. . .	. . .	2	0.07[D]	. . .	. . .	2¾	0.07[D]	. . .	. . .
15	1⅞	0.07[D]	. . .	. . .	2¼	0.07[D]	. . .	. . .	3	0.07[D]	. . .	. . .
18	2	0.07[D]	. . .	0.07[D]	2½	0.07[D]	. . .	0.07[D]	3¼	0.07[D]	. . .	0.07[D]
21	2¼	0.14	. . .	0.11	2¾	0.07[D]	. . .	0.07[D]	3½	0.07[D]	. . .	0.07[D]
24	2½	0.17	. . .	0.14	3	0.07[D]	. . .	0.07[D]	3¾	0.07	. . .	0.07[D]
27	2⅝	0.18	. . .	0.16	3¼	0.16	. . .	0.14	4	0.08	. . .	0.07[D]
30	2¾	0.19	. . .	0.18	3½	0.18	. . .	0.15	4¼	0.10	. . .	0.08
33	2⅞	0.21	. . .	0.20	3¾	0.20	. . .	0.17	4½	0.12	. . .	0.10
36	3	0.21	0.13	0.23	4 [E]	0.17	0.10	0.19	4¾[E]	0.08	0.07	0.09
42	3½	0.25	0.15	0.28	4½	0.21	0.13	0.23	5¼	0.12	0.07	0.13
48	4	0.32	0.19	0.35	5	0.24	0.14	0.27	5¾	0.16	0.10	0.18
54	4½	0.38	0.23	0.42	5½	0.29	0.17	0.32	6¼	0.21	0.13	0.23
60	5	0.44	0.26	0.49	6	0.34	0.20	0.38	6¾	0.25	0.15	0.28
66	5½	0.50	0.30	0.55	6½	0.41	0.25	0.46	7¼	0.31	0.19	0.34
72	6	0.57	0.34	0.63	7	0.49	0.29	0.54	7¾	0.36	0.22	0.40
	Concrete Strength, 5000 psi											
78	6½	0.64	0.38	0.71	7½	0.57	0.34	0.63	8¼	0.42	0.25	0.47
84	7	0.72	0.43	0.80	8	0.64	0.38	0.71	8¾	0.50	0.30	0.56
					Concrete Strength, 5000 psi				Concrete Strength, 5000 psi			
90	7½	0.81	0.49	0.90	8½	0.69	0.41	0.77	9¼	0.59	0.35	0.66
96	8	0.93	0.56	1.03	9	0.76	0.46	0.84	9¾	0.70	0.42	Inner Circular 0.28 Plus Elliptical 0.42
102	8½	1.03	0.62	Inner Circular 0.41 Plus Elliptical 0.62	9½	0.90	0.54	Inner Circular 0.36 Plus Elliptical 0.54	10¼	0.83	0.50	Inner Circular 0.33 Plus Elliptical 0.50
108	9	1.22	0.73	Inner Circular 0.49 Plus Elliptical 0.73	10	1.08	0.65	Inner Circular 0.43 Plus Elliptical 0.65	10¾	0.99	0.59	Inner Circular 0.40 Plus Elliptical 0.59
114	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
120	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
126	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
132	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
138	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
144	[A]	.. . ...	. . .	. . .	[A]	. . .	. . ....	. . .	[A]	. . .	. . .	. . .

[A] For modified or special designs see 7.2 or with the permission of the owner utilize the provisions of Specification C 655. Steel areas may be interpolated between those shown for variations in diameter, loading, or wall thickness. Pipe over 96 in. in diameter shall have two circular cages or an inner circular plus one elliptical cage.

[B] As an alternative to designs requiring both inner and outer circular cages the reinforcement may be positioned and proportioned in either of the following manners:

An inner circular cage plus an elliptical cage such that the area of the elliptical cage shall not be less than that specified for the outer cage in the table and the total area of the inner circular cage plus the elliptical cage shall not be less than that specified for the inner cage in the table,

An inner and outer cage plus quadrant mats in accordance with Fig. 1, or

An inner and outer cage plus an elliptical cage in accordance with Fig. 2.

[C] Elliptical and quadrant steel must be held in place by means of holding rods, chairs, or other positive means throughout the entire casting operation.

[D] For these classes and sizes, the minimum practical steel reinforcement is specified. The specified ultimate strength of non-reinforced pipe is greater than the minimum specified strength for the equivalent diameters.

[E] As an alternative, single cage reinforcement may be used. The reinforcement area in square in. per linear foot shall be 0.30 for wall B and 0.20 for wall C.

TABLE 4 Design Requirements for Class IV Reinforced Concrete Pipe[A]

NOTE 1—See Section 5 for basis of acceptance specified by the owner.

The strength test requirements in pounds-force per linear foot of pipe under the three-edge-bearing method shall be either the D-load (test load expressed in pounds-force per linear foot per foot of diameter) to produce a 0.01-in. crack, or the D-loads to produce the 0.01-in. crack and the ultimate load as specified below, multiplied by the internal diameter of the pipe in feet.

D-load to produce a 0.01-in. crack	2000
D-load to produce the ultimate load	3000

Internal Designated Diameter, in.	Reinforcement, in.²/linear ft of pipe wall											
	Wall A				Wall B				Wall C			
	Concrete Strength, 5000 psi				Concrete Strength, 4000 psi				Concrete Strength, 4000 psi			
	Wall Thickness, in.	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, in.	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, in.	Circular Reinforcement[B]		Elliptical Reinforcement[C]
		Inner Cage	Outer Cage			Inner Cage	Outer Cage			Inner Cage	Outer Cage	
12	1¾	0.15	...	...	2	0.07	...	...	2¾	0.07[D]	...	...
15	1⅞	0.16	...	...	2¼	0.10	...	...	3	0.07[D]	...	...
18	2	0.17	...	0.15	2½	0.14	...	0.11	3¼	0.07[D]	...	0.07[D]
21	2¼	0.23	...	0.21	2¾	0.20	...	0.17	3½	0.07[D]	...	0.07[D]
24	2½	0.29	...	0.27	3	0.27	...	0.23	3¾	0.07	0.07	0.08
27	2⅝	0.33	...	0.31	3¼	0.31	...	0.25	4	0.08	0.07	0.09
30	2¾	0.38	...	0.35	3½	0.35	...	0.28	4¼	0.09	0.07	0.10
33	[A]	...	...	...	3¾	0.27	0.16	0.30	4½	0.11	0.07	0.12
36	[A]	...	...	...	4	0.30	0.18	0.33	4¾	0.14	0.08	0.15
42	[A]	...	...	...	4½	0.35	0.21	0.39	5¼	0.20	0.12	0.22
48	[A]	...	...	...	5	0.42	0.25	0.47	5¾	0.26	0.16	0.29
54	[A]	...	...	...	5½	0.50	0.30	0.55	6¼	0.34	0.20	0.38
					Concrete Strength, 5000 psi							
60	[A]	...	...	...	6	0.59	0.35	0.66	6¾	0.41	0.25	0.46
66	[A]	...	...	...	6½	0.69	0.41	0.77	7¼	0.51	0.31	0.57
									Concrete Strength, 5000 psi			
72	[A]	...	...	...	7	0.79	0.47	0.88	7¾	0.61	0.37	0.68
78	[A]	...	...	...	[A]	...	...	...	8¼	0.71	0.43	0.79
84	[A]	...	...	...	[A]	...	...	...	8¾	0.85	0.51	0.94
90	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
96	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
102	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
108	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
114	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
120	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
126	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
132	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
138	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
144	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...

[A] For modified or special designs see 7.2 or with the permission of the owner utilize the provisions of Specification C 655. Steel areas may be interpolated between those shown for variations in diameter, loading, or wall thickness. Pipe over 96 in. in diameter shall have two circular cages or an inner circular plus one elliptical cage.

[B] As an alternative to designs requiring both inner and outer circular cages the reinforcement may be positioned and proportioned in either of the following manners:

An inner circular cage plus an elliptical cage such that the area of the elliptical cage shall not be less than that specified for the outer cage in the table and the total area of the inner circular cage plus the elliptical cage shall not be less than that specified for the inner cage in the table,

An inner and outer cage plus quadrant mats in accordance with Fig. 1, or

An inner and outer cage plus an elliptical cage in accordance with Fig. 2.

For Wall C, in sizes 24 to 33 in., a single circular cage with an area not less than the sum of the specified inner and outer circular reinforcement areas.

[C] Elliptical and quadrant steel must be held in place by means of holding rods, chairs, or other positive means throughout the entire casting operation.

[D] For these classes and sizes, the minimum practical steel reinforcement is specified.

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

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

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

6.2.4.1 Portland cement only,

6.2.4.2 Portland blast furnace slag cement only,

6.2.4.3 Slag modified portland cement only,

6.2.4.4 Portland pozzolan cement only,

6.2.4.5 A combination of portland cement and ground granulated blast-furnace slag,

6.2.4.6 A combination of portland cement and fly ash, or

6.2.4.7 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.

6.3 *Aggregates*—Aggregates shall conform to Specification C 33 except that the requirement for gradation shall not apply.

TABLE 5 Design Requirements for Class V Reinforced Concrete Pipe[A]

NOTE 1—See Section 5 for basis of acceptance specified by the owner.

The strength test requirements in pounds-force per linear foot of pipe under the three-edge-bearing method shall be either the D-load (test load expressed in pounds-force per linear foot per foot of diameter) to produce a 0.01-in. crack, or the D-loads to produce the 0.01-in. crack and the ultimate load as specified below, multiplied by the internal diameter of the pipe in feet.

D-load to produce a 0.01-in. crack	3000
D-load to produce the ultimate load	3750

Internal Designated Diameter, in.	Reinforcement, in.²/linear ft of pipe wall										
	Wall A				Wall B				Wall C		
	Concrete Strength, 6000 psi				Concrete Strength, 6000 psi				Concrete Strength, 6000 psi		
	Wall Thickness, in.	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, in.	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, in.	Circular Reinforcement[B]		Elliptical Reinforcement[C]
		Inner Cage	Outer Cage			Inner Cage	Outer Cage			Inner Cage	Outer Cage	
12	[A]	. . .	. . .	. . .	2	0.10	. . .	. . .	2¾	0.07[D]	. . .	. . .
15	[A]	. . .	. . .	. . .	2¼	0.14	. . .	. . .	3	0.07[D]	. . .	. . .
18	[A]	. . .	. . .	. . .	2½	0.19	. . .	0.16	3¼	0.10	. . .	. . .
21	[A]	. . .	. . .	. . .	2¾	0.24	. . .	0.21	3½	0.10	. . .	. . .
24	[A]	. . .	. . .	. . .	3	0.30	. . .	0.24	3¾	0.12	0.07	0.13
27	[A]	. . .	. . .	. . .	3¼	0.38	0.23	0.42	4	0.14	0.08	0.16
30	[A]	. . .	. . .	. . .	3½	0.41	0.25	0.46	4¼	0.18	0.11	0.20
33	[A]	. . .	. . .	. . .	3¾	0.46	0.28	0.51	4½	0.23	0.14	0.25
36	[A]	. . .	. . .	. . .	4	0.50	0.30	0.56	4¾	0.27	0.16	0.30
42	[A]	. . .	. . .	. . .	4½	0.60	0.36	0.67	5¼	0.36	0.22	0.40
48	[A]	. . .	. . .	. . .	5	0.73	0.44	0.81	5¾	0.47	0.28	0.52
54	[A]	. . .	. . .	. . .	[A]	. . .. .	. . .	. . .	6¼	0.58	0.35	0.64
60	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	6¾	0.70	0.42	0.78
66	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	7¼	0.84	0.50	0.93
72	[A]	. . .	. . .	. . .	[A]	. . .. .	...	. . .	7¾	0.99	0.59	1.10
78	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
84	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
90	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
96	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
102	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
108	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
114	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
120	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
126	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
132	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
138	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
144	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .	[A]	. . .	. . .	. . .
								...				

[A] For modified or special designs see 7.2 or with the permission of the owner utilize the provisions of Specification C 655. Steel areas may be interpolated between those shown for variations in diameter, loading, or wall thickness. Pipe over 96 in. in diameter shall have two circular cages or an inner circular plus one elliptical cage.

[B] As an alternative to designs requiring both inner and outer circular cages the reinforcement may be positioned and proportioned in either of the following manners:

An inner circular cage plus an elliptical cage such that the area of the elliptical cage shall not be less than that specified for the outer cage in the table and the total area of the inner circular cage plus the elliptical cage shall not be less than that specified for the inner cage in the table,

An inner and outer cage plus quadrant mats in accordance with Fig. 1, or

An inner and outer cage plus an elliptical cage in accordance with Fig. 2.

[C] Elliptical and quadrant steel must be held in place by means of holding rods, chairs, or other positive means throughout the entire casting operation.

[D] For these classes and sizes, the minimum practical steel reinforcement is specified.

6.4 *Admixtures and Blends*—The following admixtures and blends are allowable:

6.4.1 Air-entraining admixture conforming to Specification C 260;

6.4.2 Chemical admixture conforming to Specification C 494/C 494M;

6.4.3 Chemical admixture for use in producing flowing concrete conforming to Specification C 1017/C 1017M; and

6.4.4 Chemical admixture or blend approved by the owner.

6.5 *Steel Reinforcement*—Reinforcement shall consist of wire conforming to Specification A 82/A 82M or Specification A 496/A 496M; or of wire reinforcement conforming to Specification A 185/A 185M or Specification A 497/A 497M; or of bars conforming to Specification A 36/A 36M, Specification A 615/A 615M Grade 40 or 60, or Specification A 706/A 706M Grade 60.

6.6 *Synthetic Fibers*—Collated fibrillated virgin polypropylene fibers are not prohibited from being used at the manufacturer's option, 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 used.

7. Design

7.1 *Design Tables*—The diameter, wall thickness, compressive strength of the concrete, and the area of the circumferential reinforcement shall be as prescribed for Classes I to V in Tables 1-5, except as provided in 7.2.

7.1.1 The reinforcement as presented in the tables herein allows single circular cage reinforcement, or separate inner and outer circular cage reinforcement or a combination thereof. Footnotes to the tables are intended to clarify tabulated

requirements or provide acceptable alternative reinforcement designs, either of which are applicable and binding as if they were contained in the body of the specification.

7.2 *Modified and Special Designs*:

7.2.1 If permitted by the owner the manufacturer may request approval by the owner of modified designs that differ from the designs in 7.1; or special designs for sizes and loads beyond those shown in Tables 1-5, 7.1, or special designs for pipe sizes that do not have steel reinforcement areas shown in Tables 1-5 of 7.1.

7.2.2 Such modified or special designs shall be based on rational or empirical evaluations of the ultimate strength and cracking behavior of the pipe and shall fully describe to the owner any deviations from the requirements of 7.1. The descriptions of modified or special designs shall include the wall thickness, the concrete strength, and the area, type, placement, number of layers, and strength of the steel reinforcement.

7.2.3 The manufacturer shall submit to the owner proof of the adequacy of the proposed modified or special design. Such proof may comprise the submission of certified three-edge-bearing tests already made, which are acceptable to the owner or, if such three-edge-bearing tests are not available or acceptable, the manufacturer may be required to perform proof tests on sizes and classes selected by the owner to demonstrate the adequacy of the proposed design.

7.2.4 Such pipe must meet all of the test and performance requirements specified by the owner in accordance with Section 5.

7.3 *Area*—In this specification, when the word area is not described by adjectives, such as cross-section or single wire, it shall be understood to be the cross-sectional area of reinforcement per unit lengths of pipe.

8. Reinforcement

8.1 *Circumferential Reinforcement*—A line of circumferential reinforcement for any given total area may be composed of two layers for pipe with wall thicknesses of less than 7 in. or three layers for pipe with wall thicknesses of 7 in. or greater. The layers shall not be separated by more than the thickness of one longitudinal plus ¼ in. The multiple layers shall be fastened together to form a single cage. All other specification requirements such as laps, welds, and tolerances of placement in the wall of the pipe, etc., shall apply to this method of fabricating a line of reinforcement.

8.1.1 Where one line of circular reinforcement is used, it shall be placed from 35 to 50 % of the wall thickness from the inner surface of the pipe, except that for wall thicknesses less than 2½ in., the protective cover of the concrete over the circumferential reinforcement in the wall of the pipe shall be ¾ in.

8.1.2 In pipe having two lines of circular reinforcement, each line shall be so placed that the protective covering of concrete over the circumferential reinforcement in the wall of the pipe shall be 1 in.

8.1.3 In pipe having elliptical reinforcement with wall thicknesses 2½ in. or greater, the reinforcement in the wall of the pipe shall be so placed that the protective covering of concrete over the circumferential reinforcement shall be 1 in. from the inner surface of the pipe at the vertical diameter and 1 in. from the outer surface of the pipe at the horizontal diameter. In pipe having elliptical reinforcement with wall thicknesses less than 2½ in., the protective covering of the concrete shall be ¾ in. at the vertical and horizontal diameters.

8.1.4 The location of the reinforcement shall be subject to the permissible variations in dimensions given in 12.5.

8.1.5 The spacing center to center of circumferential reinforcement in a cage shall not exceed 4 in. for pipe up to and including pipe having a 4-in. wall thickness nor exceed the wall thickness for larger pipe, and shall in no case exceed 6 in.

8.1.6 Where the wall reinforcement does not extend into the joint, the maximum longitudinal distance to the last circumferential from the inside shoulder of the bell or the shoulder of the spigot shall be 3 in. except that if this distance exceeds one-half the wall thickness, the pipe wall shall contain at least a total reinforcement area of the minimum specified area per linear foot times the laying length of the pipe section. The minimum cover on the last circumferential near the spigot shoulder shall be ½ in.

8.1.6.1 Where reinforcement is in the bell or spigot the minimum end cover on the last circumferential shall be ½ in. in the bell or ¼ in. in the spigot.

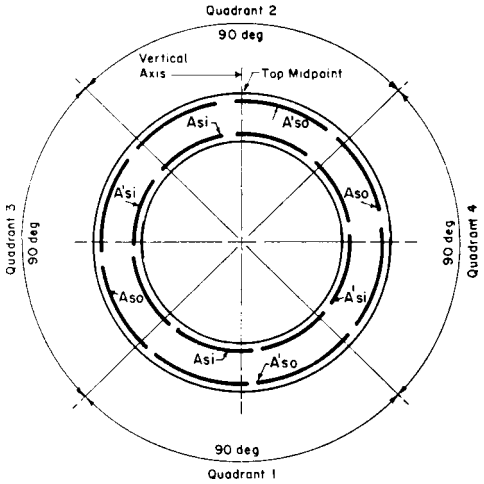
8.1.7 The continuity of the circumferential reinforcing steel shall not be destroyed during the manufacture of the pipe, except that when agreed upon by the owner, lift eyes or holes may be provided in each pipe for the purpose of handling.

8.1.8 If splices are not welded, the reinforcement shall be lapped not less than 20 diameters for deformed bars and deformed cold-worked wire, and 40 diameters for plain bars and cold-drawn wire. In addition, where lapped cages of welded-wire fabric are used without welding, the lap shall contain a longitudinal wire.

8.1.8.1 When splices are welded and are not lapped to the minimum requirements above, pull tests of representative specimens shall develop at least 50 % of the minimum specified strength of the steel, and there shall be a minimum lap of 2 in. For butt-welded splices in bars or wire, permitted only with helically wound cages, pull tests of representative specimens shall develop at least 75 % of the minimum specified strength of the steel.

8.2 *Longitudinal Reinforcement*—Each line of circumferential reinforcement shall be assembled into a cage that shall contain sufficient longitudinal bars or members, to maintain the reinforcement in shape and in position within the form to comply with permissible variations in 8.1. The exposure of the ends of longitudinals, stirrups, or spacers that have been used to position the cages during the placement of the concrete shall not be a cause for rejection.

8.3 *Joint Reinforcement*—The length of the joint as used herein means the inside length of the bell or the outside length of the spigot from the shoulder to the end of the pipe section. The end distances or cover on the end circumferential shall apply to any point on the circumference of the pipe or joint. When convoluted reinforcement is used, these distances and reinforcement areas shall be taken from the points on the convolutions closest to the end of the pipe section. Unless



NOTE 1—The total reinforcement area (Asi) of the inner cage plus the quadrant mat in Quadrants 1 and 2 shall not be less than that specified for the inner cage in Tables 1-5.

NOTE 2—The total reinforcement area (Aso) of the outer cage plus the quadrant mat in Quadrants 3 and 4 shall not be less than that specified for the outer cage in Tables 1-5.

NOTE 3—The reinforcement area (A′si) of the inner cage in Quadrants 3 and 4 shall be not less than 25 % of that specified for the inner cage in Tables 1-5.

NOTE 4—The reinforcement area (A′so) of the outer cage in Quadrants 1 and 2 shall be not less than 25 % of that specified for the outer cage in Tables 1-5.

NOTE 5—If the reinforcement area (A′so) of the outer cage in Quadrants 1 or 2 is less than 50 % of that specified for the outer cage in Tables 1-5, the quadrant mats used for the outer cage in Quadrants 3 and 4 shall extend into Quadrant 1 and 2 not less than a distance equal to the wall thickness as specified in Tables 1-5.

FIG. 1 Quadrant Reinforcement

otherwise permitted by the owner, the following requirements for joint reinforcement shall apply.

8.3.1 *Joint Reinforcement for Non-Rubber Gasket Joints*:

8.3.1.1 For pipe 36 in. and larger in diameter, either the bell or spigot shall contain circumferential reinforcement. This reinforcement shall be an extension of a wall cage, or may be a separate cage of at least the area per foot of that specified for the outer cage or one-half of that specified for single cage wall reinforcement, whichever is less.

8.3.1.2 Where bells or spigots require reinforcement, the maximum end cover on the last circumferential shall be one-half the length of the joint or 3 in., whichever is less.

8.3.2 *Joint Reinforcement for Rubber Gasket Joints*:

8.3.2.1 For pipe 12 in. and larger in diameter, the bell ends shall contain circumferential reinforcement. This reinforcement shall be an extension of the outer cage or a single wall cage, whichever is less, or may be a separate cage of at least the same area per foot with longitudinals as required in 8.2. If a separate cage is used, the cage shall extend into the pipe with the last circumferential wire at least one in. past the inside shoulder where the pipe barrel meets the bell of the joint.

8.3.2.2 Where bells require reinforcement, the maximum end cover on the last circumferential shall be 2 in.

9. Joints

9.1 The joints shall be of such design and the ends of the concrete pipe sections so formed that the pipe can be laid together to make a continuous line of pipe compatible with the permissible variations given in Section 12.

10. Manufacture

10.1 *Mixture*—The aggregates shall be sized, graded, proportioned, and mixed with such proportions of cementitious materials and water as will produce a homogeneous concrete mixture 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 6.2 and shall be added to the mix in a proportion not less than 470 lb/yd^3 unless mix designs with a lower cementitious materials content demonstrate that the quality and performance of the pipe meet the requirements of this specification.

10.2 *Curing*—Pipe shall be subjected to any one of the methods of curing described in 10.2.1 to 10.2.4 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 acceptance is based on 5.1.1 or so that the concrete will develop the specified compressive strength at 28 days or less when acceptance is based on 5.1.2.

10.2.1 *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.

10.2.2 *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.

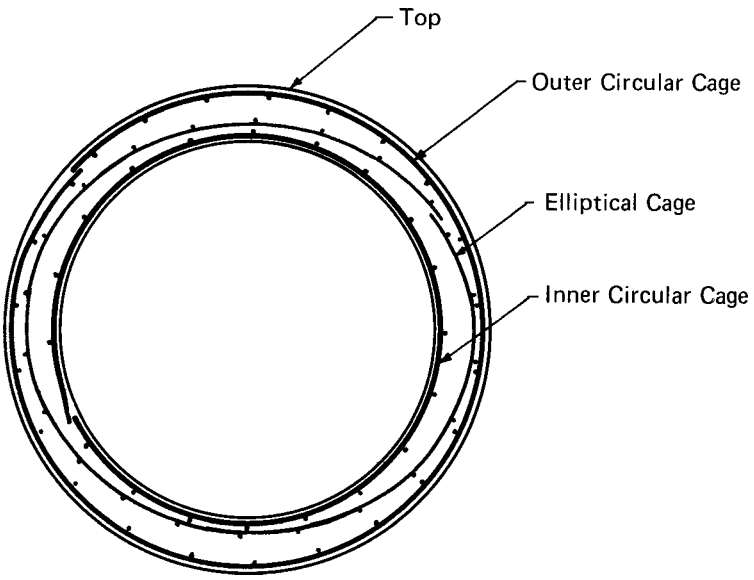
10.2.3 The manufacturer may, at his option, combine the methods described in 10.2.1 to 10.2.4 provided the required concrete compressive strength is attained.

10.2.4 A sealing membrane conforming to the requirements of Specification C 309 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.

11. Physical Requirements

11.1 *Test Specimens*—The specified number of pipe required for the tests shall be furnished without charge by the manufacturer and shall be selected at random by the owner, and shall be pipe that would not otherwise be rejected under this specification. The selection shall be made at the point or points designated by the owner when placing the order.

11.2 *Number and Type of Test Required for Various Delivery Schedules*:



NOTE 1—The total reinforcement area of the inner circular cage and the elliptical cage shall not be less than that specified for the inner cage in Tables 1-5.

NOTE 2—The total reinforcement area of the outer circular cage and the elliptical cage shall not be less than that specified for the outer cage in Tables 1-5.

FIG. 2 Triple Cage Reinforcement

11.2.1 *Preliminary Tests for Extended Delivery Schedules*—An owner of pipe, whose needs require shipments at intervals over extended periods of time, shall be entitled to such tests, preliminary to delivery of pipe, as are required by the type of basis of acceptance specified by the owner in Section 5, of not more than three sections of pipe covering each size in which he is interested.

11.2.2 *Additional Tests*—After the preliminary tests described in 11.2.1, an owner shall be entitled to additional tests at such times as the owner may deem necessary, provided that the total number of pipe tested (including preliminary tests) shall not exceed one pipe or 1 %, whichever is the greater, of each size of pipe delivered.

11.3 *External Load Crushing Strength*:

11.3.1 The load to produce a 0.01-in. crack or the ultimate load, as determined by the three-edge-bearing method as described in the Test Methods C 497 shall be not less than that prescribed in Tables 1-5 for each respective class of pipe. Pipe that support the prescribed load to produce the 0.01-in. crack and do not show a wider crack shall be considered to have met that test requirement. It is not a requirement of this speciifcation that the pipe be cracked or loaded to failure during these tests. Pipe that have been tested only to the formation of a 0.01-in. crack and that meet the 0.01-in. crack load requirements shall be accepted for use. Three-edge-bearing test to ultimate load is not required for any class of pipe 60 in. or less in diameter listed in Tables 1-5 provided all other requirements of this specification are met.

NOTE 3—As used in this specification, the 0.01-in. crack is a test criterion for pipe tested in the three-edge-bearing test and is not intended as an indication of overstressed or failed pipe under installed conditions.

11.3.2 *Retests of Pipe Not Meeting the External Load Crushing Strength Requirements*—Pipe shall be considered as meeting the strength requirements when all test specimens conform to the strength requirements. Should any of the test specimens fail to meet the strength requirements, the manufacturer shall be allowed a retest on two additional specimens for each specimen that failed, and the pipe shall be acceptable only when all of the retest specimens meet the strength requirements.

CONCRETE TESTING

11.4 *Type of Specimen*— Compression tests determining concrete compressive strength may be made on either standard rodded concrete cylinders or concrete cylinders compacted and cured in like manner as the pipe, or on cores drilled from the pipe.

11.5 *Compression Testing of Cylinders*:

11.5.1 *Cylinder Production*—Cylinders shall be prepared, cured and tested in accordance with Section 11 of Test Methods C 497.

11.5.2 *Number of Cylinders*—Prepare no fewer than five test cylinders from a group (one day's production) of pipe sections.

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

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

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

11.5.3.3 When the compressive strength of the cylinders tested does not conform to the acceptance criteria stated in 11.5.3.1 or 11.5.3.2, the acceptability of the group shall be determined in accordance with the provisions of 11.6.

11.6 *Compression Testing of Cores*:

11.6.1 *Obtaining Cores*—Cores shall be obtained and prepared in accordance with Section 6 of Test Methods C 497.

11.6.2 *Number of Cores*—One core shall be taken from a pipe section selected at random from each day's production run of a single concrete strength.

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

11.7.1 When the compressive strength of a core tested for a group of pipe sections is equal to or greater than the required concrete strength, the compressive strength of the concrete for the group is acceptable.

11.7.2 If the compressive strength of the core tested is less than the required concrete strength, two additional cores shall be taken from that pipe section and tested. Concrete represented by these three core tests shall be considered acceptable if: *(1)* the average of the three core strengths is equal to at least 85 % of the required strength and *(2)* no single core is less than 75 % of the required strength.

11.7.3 If the compressive strength of the three cores does not meet the requirements of 11.7.2, the pipe from which the cores were taken shall be rejected. Two pipe sections from the remainder of the group shall be selected at random and cored and tested for conformance with either 11.7.1 or 11.7.2. If both pipe sections meet the core strength requirements of either 11.7.1 or 11.7.2, the remainder of the group shall be acceptable. If both pipe do not meet the test strength requirement, the remainder of the group shall be either rejected or, at the option of the manufacturer, each pipe section of the remaining group shall be cored and accepted individually and any of the pipe sections that have core strengths less than the requirements of 11.7.1 or 11.7.2 shall be rejected.

11.8 *Plugging Core Holes*—Core holes shall be plugged and sealed by the manufacturer in a manner such that the pipe section will meet all of the requirements of this specification. Pipe sections so plugged and sealed shall be considered satisfactory for use.

11.9 *Absorption*—The absorption of a sample from the wall of the pipe, as determined in accordance with Test Methods C 497, 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 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 a 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.

11.10 *Retests of Pipe*—When not more than 20 % of the concrete specimens fail to pass the requirements of this specification, the manufacturer may cull the project stock and may eliminate whatever quantity of pipe desired and shall mark those pipe so that they will not be shipped. 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.

11.11 *Test Equipment*— Every manufacturer furnishing pipe under this specification shall furnish all facilities and personnel necessary to carry out the tests described in Test Methods C 497.

12. Permissible Variations

12.1 *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 ±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 for test per Section 11.

12.2 *Wall Thickness*—The wall thickness shall not vary more than shown in the design or specified wall by more than ±5 % or 3⁄16 in., whichever is greater. A specified wall thickness more than required in the design is not cause for rejection. Pipe having localized variations in wall thickness exceeding those specified above shall be accepted if the three-edge-bearing strength and minimum steel cover requirements are met.

12.3 *Length of Two Opposite Sides*—Variations in the laying length of two opposite sides of the pipe shall not be more than ¼ in. for all sizes through 24-in. internal diameter, and not more than ⅛ in./ft for all sizes larger with a maximum of ⅝ in. in any length of pipe through 84-in. internal diameter, and a maximum of ¾ in. for 90-in. internal diameter or larger, except where beveled end pipe for laying on curves is specified by the owner.

12.4 *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. Regardless of the underrun or overrun in any section of the pipe, the end cover requirements of Sections 8 and 12 shall apply.

12.5 *Position or Area of Reinforcement*:

12.5.1 *Position*—The maximum variation in the position of a line of circumferential reinforcement shall be ±10 % of the wall thickness or ±½ in., whichever is greater. Pipes having variations in the position of a line of circumferential reinforcement exceeding those specified above shall be accepted if the three-edge-bearing strength requirements obtained on a representative specimen are met. In no case, however, shall the cover over the circumferential reinforcement be less than ¼ in. as measured to the end of the spigot or ½ in. as measured to any other surface. The preceding minimum cover limitations do not apply to mating surfaces of nonrubber gasket joints or gasket grooves in rubber gasket joints. If convoluted reinforcement is used, the convoluted circumferential end wire may be at the end surface of the joint providing the alternate convolutions have at least 1 in. cover from the end surface of the joint.

12.5.2 *Area of Reinforcement*—Reinforcement will be considered as meeting the design requirements if the area, computed on the basis of nominal area of the wire or bars used, equals or exceeds the requirements of 7.1 or 7.2. Actual area of

the reinforcing used may vary from the nominal area according to permissible variations of the standard specifications for the reinforcing. When inner cage and outer cage reinforcing is used, the inner cage nominal area may vary to the lower limit of 85 % of the elliptical nominal area and the outer cage nominal area may vary to the lower limit of 51 % of the elliptical nominal area provided that the total nominal area of the inner cage plus the outer cage shall not vary beyond the lower limit of 140 % of the elliptical nominal area.

13. Repairs

13.1 Pipe may 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 may 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 10.1 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 12.3 and 12.4.

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

15.1.5 Any continuous crack having a surface width of 0.01 in. or more and extending for a length of 12 in. or more, regardless of position in the wall of the pipe.

16. Marking

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

16.1.1 The pipe class 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 plant.

16.2 One end of each section of pipe with elliptical or quadrant reinforcement shall be clearly marked during the process of manufacturing or immediately thereafter, on the inside and the outside of opposite walls along the minor axis of the elliptical reinforcing or along the vertical axis for quadrant reinforcing.

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

17. Keywords

17.1 circular pipe; culvert; D-load; pipe; reinforced concrete; sewer pipe; storm drain