Designation: C 76 – 06

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 A complete metric companion to Specification C 76 has been developed—C 76M; therefore, no metric 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 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

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.

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

[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.

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 6.1, 6.2, and 6.4; 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 6.1, 6.2, and 6.4; 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 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

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]		Elliptical Reinforcement[C]	Wall Thickness, in.	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, in.	Circular Reinforcement[C]		Elliptical Reinforcement[D]
		Inner Cage	Outer Cage			Inner Cage	Outer Cage			Inner Cage	Outer Cage	
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 Plus Elliptical	0.30 0.46	9½	0.68	0.41	Inner Circular Plus Elliptical	0.27 0.41	10¼	0.62	0.37	Inner Circular Plus Elliptical	0.25 0.37
108	9	0.85	0.51	Inner Circular Plus Elliptical	0.34 0.51	10	0.76	0.46	Inner Circular Plus Elliptical	0.30 0.46	10¾	0.70	0.42	Inner Circular Plus Elliptical	0.28 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.

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.

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.

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.

6.2.4 *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.

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

6.4.1 Air-entraining admixture conforming to Specification C 260;

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.

6.4.2 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 fabric conforming to Specification A 185/A 185M or Specification A 497/A 497M or of bars of Grade 40 steel conforming to Specification A 615/A 615M.

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