Designation: C 76 – 02

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.

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:*

A 82 Specification for Steel Wire, Plain, for Concrete Reinforcement[2]

A 185 Specification for Steel Welded Wire, Fabric, Plain, for Concrete Reinforcement[2]

A 496 Specification for Steel Wire, Deformed, for Concrete Reinforcement[2]

A 497 Specification for Steel Welded Wire Fabric, Deformed, for Concrete Reinforcement[2]

A 615/A 615M Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement[2]

C 33 Specification for Concrete Aggregates[3]

C 150 Specification for Portland Cement[4]

C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete[3]

C 497 Test Methods for Concrete Pipe, Manhole Sections, or Tile[5]

C 595 Specification for Blended Hydraulic Cements[4]

C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete[3]

C 655 Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe[5]

C 822 Terminology Relating to Concrete Pipe and Related Products[5]

C 1116 Specification for Fiber-Reinforced Concrete and Shotcrete[3]

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, two separate and alternative bases of acceptance are permitted as follows:

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 absorption tests on selected samples of concrete from the wall of the pipe; 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

[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] *Annual Book of ASTM Standards*, Vol 01.04.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

[4] *Annual Book of ASTM Standards*, Vol 04.01.

[5] *Annual Book of ASTM Standards*, Vol 04.05.

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 Plus Elliptical 0.38	9½	0.54	0.32	Inner Circular 0.22 Plus Elliptical 0.32
108	9	0.68	0.41	Inner Circular 0.27 Plus Elliptical 0.41	10	0.61	0.37	Inner Circular 0.24 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.

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 absorption tests on selected samples from the wall of the pipe; 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 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 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.

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

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

6.2.3.1 Portland cement only,

6.2.3.2 Portland blast furnace slag cement only,

6.2.3.3 Portland pozzolan cement only, or

6.2.3.4 A combination of portland cement and fly ash.

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

6.4 *Admixtures and Blends*—Admixtures and blends may be

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 0.46	9½	0.68	0.41	Inner Circular Plus Elliptical 0.41	10¼	0.62	0.37	Inner Circular Plus Elliptical 0.37
108	9	0.85	0.51	Inner Circular Plus Elliptical 0.51	10	0.76	0.46	Inner Circular Plus Elliptical 0.46	10¾	0.70	0.42	Inner Circular 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 actual ultimate strength is greater than the minimum strength specified for nonreinforced pipe of 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.

used with the approval of the owner.

6.5 *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.

6.6 *Synthetic Fibers*— Collated fibrillated virgin polypropylene fibers may 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. 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.

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 actual ultimate strength is greater than the minimum strength specified for nonreinforced pipe of 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.

7.1.1 Footnotes to the tables herein are intended to be amplifications of tabulated requirements and are to be considered 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

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.

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.