Designation: C76 – 20

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

This standard is issued under the fixed designation C76; 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 U.S. 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 C76M; therefore, no SI equivalents are presented in this specification. Reinforced concrete pipe that conform to the requirements of C76M, are acceptable under this Specification C76 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 C655).

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A36/A36M Specification for Carbon Structural Steel

A615/A615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

A706/A706M Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement

A1064/A1064M Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete

C33/C33M Specification for Concrete Aggregates

C76M Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe (Metric)

C150/C150M Specification for Portland Cement

C260/C260M Specification for Air-Entraining Admixtures for Concrete

C309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete

C443 Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets

C494/C494M Specification for Chemical Admixtures for Concrete

C497 Test Methods for Concrete Pipe, Concrete Box Sections, Manhole Sections, or Tile

C595/C595M Specification for Blended Hydraulic Cements

C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

C655 Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe

C822 Terminology Relating to Concrete Pipe and Related Products

C989/C989M Specification for Slag Cement for Use in Concrete and Mortars

C990 Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants

C1017/C1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete

C1116/C1116M Specification for Fiber-Reinforced Concrete

C1602/C1602M Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete

C1628 Specification for Joints for Concrete Gravity Flow Sewer Pipe, Using Rubber Gaskets

3. Terminology

3.1 *Definitions*—For definitions of terms relating to concrete pipe, see Terminology C822.

[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.

***A Summary of Changes section appears at the end of this standard**

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 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 as required in 11.9; and by visual inspection of the finished pipe to determine its conformance with the accepted material requirements 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 7.2 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 *Reinforced Concrete*—The reinforced concrete shall consist of cementitious materials; mineral aggregates; admixtures, if used; and water in which steel has been embedded in such a manner that the steel and concrete act together.

TABLE 1 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.	Wall A				Wall B			
	Concrete Strength, 4000 psi				Concrete Strength, 4000 psi			
	Reinforcement, in.²/linear ft of pipe wall							
	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]
60	5	0.24	0.15	0.27	6	0.21	0.12	0.23
66	5½	0.30	0.18	0.33	6½	0.24	0.15	0.27
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	0.36	0.21	0.41
90	7½	0.49	0.29	0.54	8½	0.41	0.24	0.45
96	8	0.54	0.32	0.60	9	0.45	0.27	0.51
	Concrete Strength, 5000 psi							
102	8½	0.63	0.38	Inner Circular 0.24 Plus Elliptical 0.38	9½	0.54	0.32	Inner Circular 0.21 Plus Elliptical 0.32
108	9	0.68	0.41	Inner Circular 0.27 Plus Elliptical 0.41	10	0.60	0.36	Inner Circular 0.24 Plus Elliptical 0.36
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 C655. 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 configurations 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.

TABLE 2 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[B]		Elliptical Reinforcement[C]
		Inner Cage	Outer Cage			Inner Cage	Outer Cage			Inner Cage	Outer Cage	
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	0.12	...	0.10	2¾	0.07[D]	...	0.07[D]	3½	0.07[D]	...	0.07[D]
24	2½	0.12	...	0.11	3	0.07[D]	...	0.07[D]	3¾	0.07[D]	...	0.07[D]
27	2⅝	0.15	...	0.12	3¼	0.12	...	0.11	4	0.07[D]	...	0.07[D]
30	2¾	0.15	...	0.14	3½	0.14	...	0.12	4¼	0.07[D]	...	0.07[D]
33	2⅞	0.16	...	0.15	3¾	0.15	...	0.12	4½	0.07[D]	...	0.07[D]
36	3	0.14	0.08	0.15	4[E]	0.12	0.07	0.12	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	0.12	0.23	5	0.18	0.11	0.20	5¾	0.14	0.08	0.15
54	4½	0.24	0.15	0.27	5½	0.21	0.12	0.24	6¼	0.17	0.10	0.19
60	5	0.30	0.18	0.33	6	0.24	0.15	0.27	6¾	0.21	0.12	0.24
66	5½	0.35	0.21	0.39	6½	0.31	0.19	0.34	7¼	0.24	0.15	0.27
72	6	0.41	0.24	0.45	7	0.35	0.21	0.39	7¾	0.30	0.18	0.33
78	6½	0.45	0.27	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	0.45	0.27	0.51	8¾	0.41	0.24	0.45
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	0.36	0.69	9	0.57	0.34	0.63	9¾	0.55	0.33	0.60
	Concrete Strength, 5000 psi											
102	8½	0.76	0.45	Inner Circular Plus Elliptical 0.30 / 0.45	9½	0.68	0.41	Inner Circular Plus Elliptical 0.27 / 0.41	10¼	0.62	0.36	Inner Circular Plus Elliptical 0.24 / 0.36
108	9	0.85	0.51	Inner Circular Plus Elliptical 0.34 / 0.51	10	0.76	0.45	Inner Circular Plus Elliptical 0.30 / 0.45	10¾	0.70	0.42	Inner Circular Plus Elliptical 0.27 / 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 C655. 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 configurations 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 0.20 for wall B and 0.16 for wall C.

6.2 *Cementitious materials:*

6.2.1 *Cement*—Cement shall conform to the requirements of Specification C150/C150M, or shall be portland blast-furnace slag cement, portland-limestone cement, or portland-pozzolan cement conforming to the requirements of Specification C595/C595M, except that the pozzolan constituent in the Type IP portland-pozzolan cement shall be fly ash.

6.2.2 *Slag Cement*—Slag cement shall conform to the requirements of Grade 100 or 120 of Specification C989/C989M.

6.2.3 *Fly Ash*—Fly ash shall conform to the requirements of Class F or Class C of Specification C618.

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 Portland-pozzolan cement only,

6.2.4.4 Portland-limestone cement only,

TABLE 3 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

Reinforcement, in.^{2}/linear ft of pipe wall

Internal Designated Diameter, in.	Wall A				Wall B				Wall C			
	Concrete Strength, 4000 psi				Concrete Strength, 4000 psi				Concrete Strength, 4000 psi			
	Wall Thick-nesses, in.	Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]	Wall Thick-nesses, in.	Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]	Wall Thick-nesses, 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	0.12	0.23	4 [E]	0.17	0.10	0.19	4¾ [E]	0.08	0.07	0.09
42	3½	0.24	0.15	0.27	4½	0.21	0.12	0.23	5¼	0.12	0.07	0.12
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	0.12	0.23
60	5	0.44	0.26	0.49	6	0.34	0.20	0.38	6¾	0.24	0.15	0.27
66	5½	0.50	0.30	0.55	6½	0.41	0.24	0.45	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	0.21	0.40
	Concrete Strength, 5000 psi											
78	6½	0.64	0.38	0.71	7½	0.57	0.34	0.63	8¼	0.42	0.24	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	0.45	0.84	9¾	0.70	0.42	Inner Circular 0.27 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 C655. 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 configurations 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.

6.2.4.5 A combination of portland cement or portland-limestone cement and slag cement,

6.2.4.6 A combination of portland cement or portland-limestone cement and fly ash,

6.2.4.7 A combination of portland cement or portland-limestone cement, slag cement and fly ash, or

6.2.4.8 A combination of portland-pozzolan cement and fly ash.

TABLE 4 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	...	0.24	4	0.08	0.07	0.09
30	2¾	0.38	...	0.35	3½	0.35	...	0.27	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	0.21
48	[A]	...	...	...	5	0.42	0.24	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	0.24	0.45
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	0.60	0.36	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 C655. 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 configurations 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.

6.3 *Aggregates*—Aggregates shall conform to Specification C33/C33M except that the requirement for gradation shall not apply.

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

6.4.1 Air-entraining admixture conforming to Specification C260/C260M;

6.4.2 Chemical admixture conforming to Specification C494/C494M;

6.4.3 Chemical admixture for use in producing flowing concrete conforming to Specification C1017/C1017M; and

6.4.4 Chemical admixture or blend approved by the owner.

6.5 *Steel Reinforcement*—Reinforcement shall consist of wire or welded wire conforming to Specification A1064/A1064M, or of bars conforming to Specification A36/A36M, Specification A615/A615M, Grade 40 or 60, or Specification A706/A706M, Grade 60. For helically wound cages only, weld shear tests are not required.

6.6 *Fibers*—Synthetic fibers and nonsynthetic fibers shall be allowed to be used, at the manufacturer's option, in concrete pipe as a nonstructural manufacturing material. Synthetic fibers

TABLE 5 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	0.12
27	[A]	...	...	...	3¼	0.38	0.23	0.42	4	0.14	0.08	0.16
30	[A]	...	...	...	3½	0.41	0.24	0.45	4¼	0.18	0.11	0.20
33	[A]	...	...	...	3¾	0.45	0.27	0.51	4½	0.23	0.14	0.24
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	0.21	0.40
48	[A]	...	...	...	5	0.73	0.44	0.81	5¾	0.47	0.27	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 C655. 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 configurations 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.

(Type II and Type III) and nonsynthetic fiber (Type I) designed and manufactured specifically for use in concrete and conforming to the requirements of Specification C1116/C1116M shall be accepted.

6.7 *Water*—Water used in the production of concrete shall be potable or nonpotable water that meets the requirements of Specification C1602/C1602M.

7. Design

7.1 *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 configurations, 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 configurations 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.

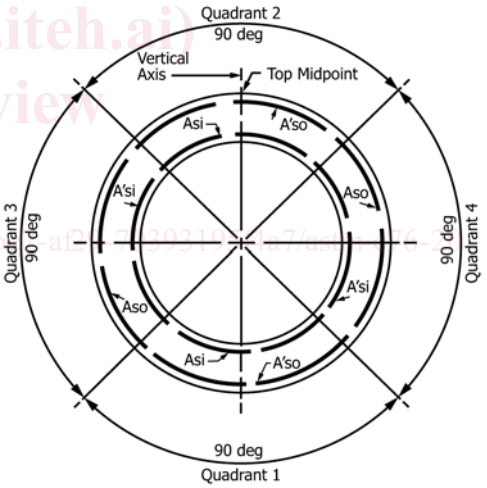
8.1.6 Where the wall reinforcement does not extend into the joint, the maximum longitudinal distance to the last circumferential from the inside shoulder of the bell or the shoulder of the spigot shall be 3 in. except that if this distance exceeds one-half the wall thickness, the pipe wall shall contain 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, there shall be a minimum lap of 2 in. and a weld such that pull tests of representative specimens



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