Designation: C76M – 12

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

This standard is issued under the fixed designation C76M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

1. Scope

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

1.2 This specification is the SI companion to Specification C76.

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, controlled manufacture in the plant, and care and 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 (ASTM Designation C655M).

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 Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
A1064/A1064M Specification for Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
C33 Specification for Concrete Aggregates
C150 Specification for Portland Cement
C260 Specification for Air-Entraining Admixtures for Concrete
C309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete
C494/C494M Specification for Chemical Admixtures for Concrete
C497M Test Methods for Concrete Pipe, Manhole Sections, or Tile [Metric]
C595 Specification for Blended Hydraulic Cements
C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
C655M Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe (Metric)
C822 Terminology Relating to Concrete Pipe and Related Products
C989 Specification for Slag Cement for Use in Concrete and Mortars
C1017/C1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete
C1116 Specification for Fiber-Reinforced Concrete and Shotcrete

3. Terminology

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

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

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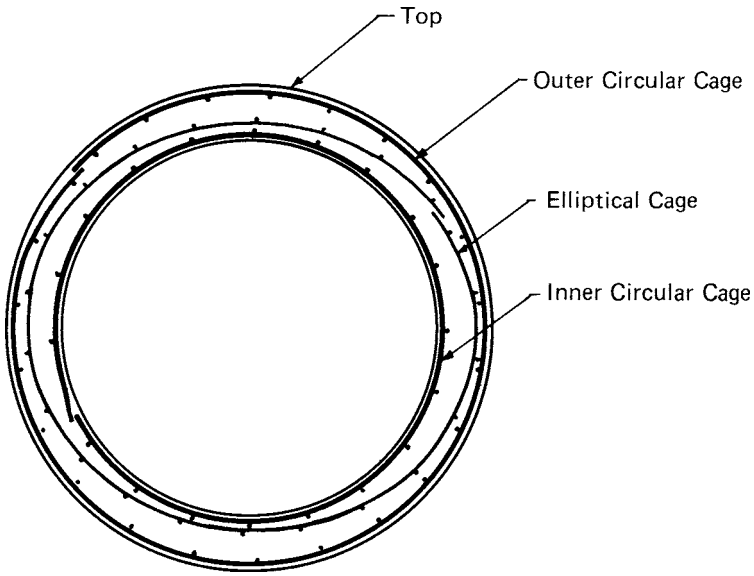
[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



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

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

FIG. 1 Triple Cage Reinforcement

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

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

The strength test requirements in newtons per linear metre of pipe under the three-edge-bearing method shall be either the D-load (test load expressed in newtons per linear metre per millimetre of diameter) to produce the 0.3-mm crack, or the D-loads to produce the 0.3-mm crack and the ultimate load as specified below, multiplied by the internal diameter of the pipe in millimetres.

D-load to produce a 0.3 mm crack	40.0
D-load to produce the ultimate load	60.0

Internal Designated Diameter, mm	Reinforcement, cm²/linear m of pipe wall							
	Wall A				Wall B			
	Concrete Strength, 27.6 MPa				Concrete Strength, 27.6 MPa			
	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]
		Inner Cage	Outer Cage			Inner Cage	Outer Cage	
1500	125	5.3	3.2	5.9	150	4.4	2.6	4.9
1650	138	6.4	3.8	7.0	163	5.3	3.2	5.9
1800	150	7.4	4.4	8.3	175	6.1	3.7	6.8
1950	163	8.5	5.1	9.3	188	6.8	4.1	7.6
2100	175	9.5	5.7	10.6	200	7.8	4.7	8.7
2250	188	10.4	6.2	11.4	213	8.7	5.2	9.7
2400	200	11.4	6.8	12.7	225	9.7	5.8	10.8
	Concrete Strength, 34.5 MPa							
2550	213	13.3	8.0	Inner Circular 5.3 Plus Elliptical 8.0	238	11.4	6.8	Inner Circular 4.6 Plus Elliptical 6.8
2700	225	14.4	8.6	Inner Circular 5.8 Plus Elliptical 8.6	250	12.9	7.7	Inner Circular 5.2 Plus Elliptical 7.7
2850	[A]	...	...	... ...	[A]	...	...	... ...
3000	[A]	...	...	... ...	[A]	...	...	... ...
3150	[A]	...	...	... ...	[A]	...	...	... ...
3300	[A]	...	...	... ...	[A]	...	...	... ...
3450	[A]	...	...	... ...	[A]	...	...	... ...
3600	[A]	...	...	... ...	[A]	...	...	... ...

[A] For modified or special designs, see 7.2 or with the permission of the owner utilize the provisions of Specification C655M. Steel areas may be interpolated between those shown for variations in diameter, loading, or wall thickness. Pipe over 2400 mm 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. 2, or

An inner and outer cage plus an elliptical cage in accordance with Fig. 1.

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

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

The strength test requirements in newtons per linear metre of pipe under the three-edge-bearing method shall be either the D-load (test-load expressed in newtons per linear metre per millimetre of diameter) to produce the 0.3-mm crack, or the D-loads to produce the 0.3-mm crack and the ultimate load as specified below, multiplied by the internal diameter of the pipe in millimetres.

D-load to produce a 0.3 mm crack	50.0
D-load to produce the ultimate load	75.0

Internal Designated Diameter, mm	Reinforcement, cm^2/linear m of pipe wall											
	Wall A				Wall B				Wall C			
	Concrete Strength, 27.6 MPa				Concrete Strength, 27.6 MPa				Concrete Strength, 27.6 MPa			
	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]
		Inner Cage	Outer Cage			Inner Cage	Outer Cage			Inner Cage	Outer Cage	
300	44	1.5[D]	...	...	50	1.5[D]	...	...	69	1.5[D]	...	...
375	47	1.5[D]	...	...	57	1.5[D]	...	...	75	1.5[D]	...	...
450	50	1.5[D]	...	1.5	63	1.5[D]	...	1.5[D]	82	1.5[D]	...	1.5[D]
525	57	2.5	...	2.1	69	1.5[D]	...	1.5[D]	88	1.5[D]	...	1.5[D]
600	63	2.8	...	2.3	75	1.5[D]	...	1.5[D]	94	1.5[D]	...	1.5[D]
675	66	3.2	...	2.8	82	2.8	...	2.3	100	1.5[D]	...	1.5[D]
750	69	3.2	...	3.0	88	3.0	...	2.5	106	1.5[D]	...	1.5[D]
825	72	3.4	...	3.2	94	3.2	...	2.8	113	1.5[D]	...	1.5[D]
900	75	3.0	1.8	3.2	100[E]	2.5	1.5	2.8	119[E]	1.5	1.5	1.7
1050	88	3.4	2.0	3.8	113	3.2	1.9	3.6	132	2.1	1.5	2.3
1200	100	4.5	2.7	4.9	125	3.8	2.3	4.2	144	3.0	1.8	3.2
1350	113	5.3	3.2	5.9	138	4.7	2.8	5.1	157	3.6	2.2	4.0
1500	125	6.4	3.8	7.0	150	5.3	3.2	5.9	169	4.7	2.8	5.1
1650	138	7.4	4.4	8.3	163	6.6	4.0	7.2	182	5.3	3.2	5.9
1800	150	8.7	5.2	9.5	175	7.4	4.4	8.3	194	6.4	3.8	7.0
1950	163	9.7	5.8	10.8	188	8.5	5.1	9.3	207	7.4	4.4	8.3
2100	175	10.8	6.5	12.1	200	9.7	5.8	10.8	219	8.7	5.2	9.7
2250	188	12.1	7.3	13.3	213	10.8	6.5	12.1	232	10.2	6.1	11.2
2400	200	13.1	7.9	14.6	225	12.1	7.3	13.3	244	11.6	7.0	12.9
	Concrete Strength, 34.5 MPa											
2550	213	16.1	9.7	Inner Circular 6.4 Plus Elliptical 9.7	238	14.4	8.6	Inner Circular 5.8 Plus Elliptical 8.6	257	13.1	7.9	Inner Circular 5.2 Plus Elliptical 7.9
2700	225	18.0	10.8	Inner Circular 7.2 Plus Elliptical 10.8	250	16.1	9.7	Inner Circular 6.4 Plus Elliptical 9.7	269	14.8	8.9	Inner Circular 5.9 Plus Elliptical 8.9
2850	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...
3000	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...
3150	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...
3300	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...
3450	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...
3600	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...

[A] For modified or special designs, see 7.2 or with the permission of the owner utilize the provisions of Specification C655M. Steel areas may be interpolated between those shown for variations in diameter, loading, or wall thickness. Pipe over 2400 mm 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. 2, or

An inner and outer cage plus an elliptical cage in accordance with Fig. 1.

[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 centimetres per linear metre shall be 4.2 for wall B and 3.4 for wall C.

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 design and its freedom from defects.

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

5.1.3 When agreed upon between 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.

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

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

The strength test requirements in newtons per linear metre of pipe under the three-edge-bearing method shall be either the D-load (test-load expressed in newtons per linear metre per millimetre of diameter) to produce the 0.3-mm crack, or the D-loads to produce the 0.3-mm crack and the ultimate load as specified below, multiplied by the internal diameter of the pipe in millimetres.

D-load to produce a 0.3 mm crack	65.0
D-load to produce the ultimate load	100.0

Internal Designated Diameter, mm	Reinforcement, cm^2/linear m of pipe wall											
	Wall A				Wall B				Wall C			
	Concrete Strength, 27.6 MPa				Concrete Strength, 27.6 MPa				Concrete Strength, 27.6 MPa			
	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]
		Inner Cage	Outer Cage			Inner Cage	Outer Cage			Inner Cage	Outer Cage	
300	44	1.5[D]	...	...	50	1.5[D]	[D]	...	69	1.5[D]	...	...
375	47	1.5[D]	...	...	57	1.5[D]	...	...	75	1.5[D]	...	...
450	50	1.5[D]	...	1.5[D]	63	1.5[D]	...	1.5[D]	82	1.5[D]	...	1.5[D]
525	57	3.0	...	2.3	69	1.5[D]	...	1.5[D]	88	1.5[D]	...	1.5[D]
600	63	3.6	...	3.0	75	1.5[D]	...	1.5[D]	94	1.5[D]	...	1.5[D]
675	66	3.8	...	3.4	82	3.4	...	3.0	100	1.7	...	1.5[D]
750	69	4.0	...	3.8	88	3.8	...	3.2	107	2.1	...	1.7
825	72	4.4	...	4.2	94	4.2	...	3.6	113	2.5	...	2.1
900	75	4.4	2.6	4.7	100[E]	3.6	2.2	4.0	119[E]	1.7	1.5	1.9
1050	88	5.3	3.2	5.9	113	4.4	2.6	4.9	132	2.5	1.5	2.8
1200	100	6.8	4.1	7.4	125	5.1	3.1	5.7	144	3.4	2.0	3.8
1350	113	8.0	4.8	8.9	138	6.1	3.7	6.8	157	4.4	2.6	4.9
1500	125	9.3	5.6	10.4	150	7.2	4.3	8.0	169	5.3	3.2	5.9
1650	138	10.6	6.4	11.6	163	9.1	5.5	9.7	182	6.6	4.0	7.2
1800	150	12.1	7.3	13.3	175	10.4	6.2	11.4	194	7.6	4.6	8.5
	Concrete Strength, 34.5 MPa											
1950	163	13.5	8.1	15.0	188	12.1	7.3	13.3	207	8.9	5.3	9.9
2100	175	15.2	9.1	16.9	200	13.5	8.1	15.0	219	10.6	6.4	11.9
					Concrete Strength, 34.5 MPa				Concrete Strength, 34.5 MPa			
2250	188	17.1	10.3	19.1	213	14.6	8.8	16.3	232	12.5	7.5	14.0
2400	200	19.7	11.8	21.8	225	16.1	9.7	17.8	244	14.8	8.9	Inner Circular 5.9 Plus Elliptical 8.9
2550	213	21.8	13.1	Inner Circular 8.7 Plus Elliptical 13.1	238	19.1	11.5	Inner Circular 7.6 Plus Elliptical 11.5	257	17.6	10.6	Inner Circular 7.0 Plus Elliptical 10.6
2700	225	25.8	15.5	Inner Circular 10.3 Plus Elliptical 15.5	250	22.9	13.7	Inner Circular 9.2 Plus Elliptical 13.7	269	21.0	12.6	Inner Circular 8.4 Plus Elliptical 12.6
2850	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...
3000	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...
3150	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...
3300	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...
3450	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...
3600	[A]	...	...	... ...	[A]	...	...	... ...	[A]	...	...	... ...

[A] For modified or special designs, see 7.2 or with the permission of the owner utilize the provisions of Specification C655M. Steel areas may be interpolated between those shown for variations in diameter, loading, or wall thickness. Pipe over 2400 mm 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. 2, or

An inner and outer cage plus an elliptical cage in accordance with Fig. 1.

[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 centimetres per linear metre shall be 6.4 for wall B and 4.2 for wall C.

6. Materials

6.1 *Reinforced Concrete*—The reinforced concrete shall consist of cementitious materials, mineral aggregates, and water, in which steel has been embedded in such a manner that the steel and concrete act together.

6.2 *Cementitious Materials:*

6.2.1 *Cement*—Cement shall conform to the requirements for portland cement of Specification C150 or shall be portland blast-furnace slag cement or slag modified portland cement, or portland-pozzolan cement conforming to the requirements of Specification C595, 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 shall conform to the requirements of Grade 100 or 120 of Specification C989.

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:

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

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

The strength test requirements in newtons per linear metre of pipe under the three-edge-bearing method shall be either the D-load (test load expressed in newtons per linear metre per millimetre of diameter) to produce the 0.3-mm crack, or the D-loads to produce the 0.3-mm crack and the ultimate load as specified below, multiplied by the internal diameter of the pipe in millimetres.

D-load to produce a 0.3 mm crack	100.0
D-load to produce the ultimate load	150.0

Internal Designated Diameter, mm	Reinforcement, cm^2/linear m of pipe wall											
	Wall A				Wall B				Wall C			
	Concrete Strength, 34.5 MPa				Concrete Strength, 27.6 MPa				Concrete Strength, 27.6 MPa			
	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]
		Inner Cage	Outer Cage			Inner Cage	Outer Cage			Inner Cage	Outer Cage	
300	44	3.2	...	...	50	1.5	...	...	69	1.5[D]	...	...
375	47	3.4	...	...	57	2.1	...	...	75	1.5[D]	...	...
450	50	3.6	...	3.2	63	3.0	...	2.3	82	1.5[D]	...	1.5[D]
525	57	4.9	...	4.4	69	4.2	...	3.6	88	1.5[D]	...	1.5[D]
600	63	6.1	...	5.7	75	5.7	...	4.9	94	1.5	1.5	1.7
675	66	7.0	...	6.6	82	6.6	...	5.3	100	1.7	1.5	1.9
750	69	8.0	...	7.4	88	7.4	...	5.9	107	1.9	1.5	2.1
825	[A]	...	...	...	94	5.7	3.4	6.3	113	2.3	1.5	2.5
900	[A]	...	...	...	100	6.3	3.8	7.0	119	3.0	1.8	3.2
1050	[A]	...	...	...	113	7.4	4.4	8.3	132	4.2	2.5	4.7
1200	[A]	...	...	...	125	8.9	5.3	9.9	144	5.5	3.3	6.1
1350		...	...	...	138	10.6	6.4	11.6	157	7.2	4.3	8.0
					Concrete Strength, 34.5 MPa							
1500	[A]	...	...	...	150	12.5	7.5	14.0	169	8.7	5.2	9.7
1650	[A]	...	...	...	163	14.6	8.8	16.3	182	10.8	6.5	12.0
									Concrete Strength, 34.5 MPa			
1800	[A]	...	...	...	175	16.7	10.0	18.6	194	12.9	7.7	14.4
1950	[A]	...	...	...	[A]	...	...	...	207	15.0	9.0	16.7
2100	[A]	...	...	...	[A]	...	...	...	219	18.0	10.8	19.9
2250	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
2400	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
						...	...	...	[A]	...	...	...
2550	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
2700	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
2850	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
3000	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
3150	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
3300	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
3450	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
3600	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...

[A] For modified or special designs see 7.2 or with the permission of the owner utilize the provisions of Specification C655M. Steel areas may be interpolated between those shown for variations in diameter, loading, or wall thickness. Pipe over 2400 mm 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. 2, or

An inner and outer cage plus an elliptical cage in accordance with Fig. 1.

For Wall C, in sizes 600 to 825 mm, 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.

6.2.4.1 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).

6.2.4.8 A combination of portland pozzolan cement and fly ash, provided the fly ash added does not exceed 25 % by weight of the portland pozzolan cement.

6.3 *Aggregates*—Aggregates shall conform to Specification C33 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 C260;

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 conforming to Specification A1064/A1064M; or of bars

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

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

The strength test requirements in newtons per linear metre of pipe under the three-edge-bearing method shall be either the D-load (test load expressed in newtons per linear metre per millimetre of diameter) to produce the 0.3-mm crack, or the D-loads to produce the 0.3-mm crack and the ultimate load as specified below, multiplied by the internal diameter of the pipe in millimetres.

D-load to produce a 0.3 mm crack	140.0
D-load to produce the ultimate load	175.0

Internal Designated Diameter, mm	Reinforcement, cm^2/linear m of pipe wall											
	Wall A				Wall B				Wall C			
	Concrete Strength, 41.4 MPa				Concrete Strength, 41.4 MPa				Concrete Strength, 41.4 MPa			
	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]	Wall Thickness, mm	Circular Reinforcement[B]		Elliptical Reinforcement[C]
		Inner Cage	Outer Cage			Inner Cage	Outer Cage			Inner Cage	Outer Cage	
300	[A]	...	...	...	50	2.1	...	...	69	1.5[D]	...	...
375	[A]	...	...	...	57	3.0	...	...	75	1.5[D]	...	...
450	[A]	...	...	...	63	4.0	...	3.4	82	2.1	...	...
525	[A]	...	...	...	69	5.1	...	4.4	88	2.1	...	...
600	[A]	...	...	...	75	6.4	...	5.1	94	2.5	1.5	2.8
675	[A]	...	...	...	82	8.0	4.8	8.9	100	3.0	1.8	3.4
750	[A]	...	...	...	88	8.7	5.2	9.7	107	3.8	2.3	4.2
825	[A]	...	...	...	94	9.7	5.8	10.8	113	4.9	2.9	5.3
900	[A]	...	...	...	100	10.6	6.4	11.9	119	5.7	3.4	6.3
1050	[A]	...	...	...	113	12.7	7.6	14.2	132	7.6	4.6	8.5
1200	[A]	...	...	...	125	15.5	9.3	17.1	144	9.9	5.9	11.0
1350	[A]	...	...	...	[A]	...	...	...	157	12.3	7.4	13.5
1500	[A]	...	...	...	[A]	...	...	...	169	14.8	8.9	16.5
1650	[A]	...	...	...	[A]	...	...	...	182	17.8	10.7	19.7
1800	[A]	...	...	...	[A]	...	...	...	194	21.0	12.6	23.3
1950	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
2100	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
2250	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
2400	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
2550	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
2700	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
2850	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
3000	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
3150	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
3300	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
3450	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...
3600	[A]	...	...	...	[A]	...	...	...	[A]	...	...	...

[A] For modified or special designs see 7.2 or with the permission of the owner utilize the provisions of Specification C655M.

[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. 2, or
An inner and outer cage plus an elliptical cage in accordance with Fig. 1.

[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.

conforming to Specification A36/A36M, Specification A615/A615M Grade 40 or 60, or Specification A706/A706M Grade 60.

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 C1116 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.

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 single elliptical cage reinforcement or a combination thereof.

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

7.2 *Modified and Special Designs:*

7.2.1 If permitted by the owner the manufacturer may request approval by the owner of modified designs that differ from the designs in; 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.