Designation: C76M – 18

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 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 SI companion to Specification C76; therefore, no inch-pound equivalents are presented in this specification. Reinforced concrete pipe that conform to the requirements of C76 are acceptable under this Specification C76M 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, 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).

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
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
C443M Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets (Metric)
C494/C494M Specification for Chemical Admixtures for Concrete
C497M Test Methods for Concrete Pipe, Manhole Sections, or Tile (Metric)
C595/C595M 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/C989M Specification for Slag Cement for Use in Concrete and Mortars
C990M Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants (Metric)
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 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.

6. Materials

6.1 *Reinforced Concrete*—The reinforced concrete shall consist of cementitious materials, mineral aggregates, water, and admixtures, if any, 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/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.

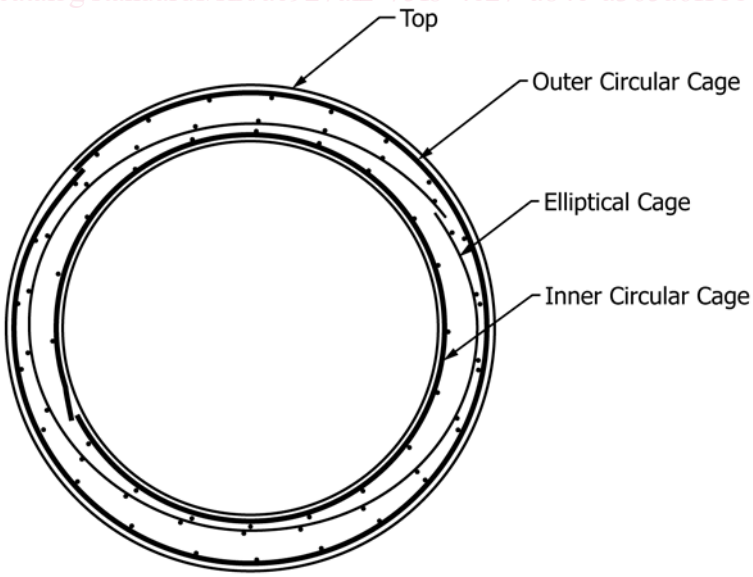
6.2.3 *Fly Ash*—Fly ash shall conform to the requirements of Class F or Class C of Specification C618.

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,



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, cm^2/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 Plus Elliptical	5.3 8.0	238	11.4	6.8	Inner Circular Plus Elliptical	4.6 6.8
2700	225	14.4	8.6	Inner Circular Plus Elliptical	5.8 8.6	250	12.9	7.7	Inner Circular Plus Elliptical	5.2 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.

6.2.4.4 Portland-limestone cement only,

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.

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 and welded wire conforming to Specification A1064/A1064M, or of bars conforming to Specification A36/A36M, Specification A615/A615M Grade 280 or 420, or Specification A706/A706M Grade 420. 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 (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.

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.

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 *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

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.

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.

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.

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] 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.

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 180 mm or three layers for pipe with wall thicknesses of 180 mm or greater. The layers shall not be separated by more than the thickness of one longitudinal plus 6 mm. 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 63 mm, the protective cover of the concrete over the circumferential reinforcement in the wall of the pipe shall be 19 mm.

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 25 mm.