METRIC
Designation: C 76M – 02~~3~~

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

This standard is issued under the fixed designation C 76M; 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 metric counterpart of Specification C 76.

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 C 655M).

2. Referenced Documents

2.1 *ASTM Standards:*

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[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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A 82 Specification for Steel Wire, Plain, for Concrete Reinforcement[2]
A 185 Specification for Steel Welded Wire Reinforcement, Plain, for Concrete[2]
A 496 Specification for Steel Wire, Deformed, for Concrete Reinforcement[2]
A 497 Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete[2]
A 615/A 615M Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement[2]
C 33 Specification for Concrete Aggregates[3]
C 150 Specification for Portland Cement[4]
C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete[3]
C 497M Test Methods for Concrete Pipe, Manhole Sections, or Tile [Metric][5]
C 595 Specification for Blended Hydraulic Cements[4]
C 618 Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete[3]
C 655M Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe [Metric][5]
C 822 Terminology Relating to Concrete Pipe and Related Products[5]
C 1116 Specification for Fiber-Reinforced Concrete and Shotcrete[3]

3. Terminology

3.1 *Definitions*—For definitions of terms relating to concrete pipe, see Terminology C 822.

4. Classification

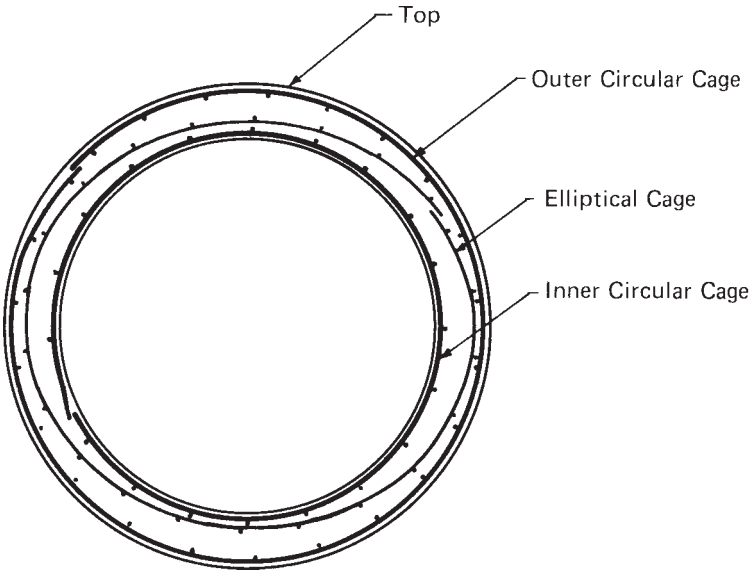
4.1 Pipe manufactured in accordance with this specification shall be of five classes identified as Class I, Class II, Class III, Class IV, and Class V. The corresponding strength requirements are prescribed in Tables 1-5.

5. Basis of Acceptance

5.1 Unless otherwise designated by the owner at the time of, or before placing an order, two separate and alternative bases of acceptance are permitted as follows:

5.1.1 *Acceptance on the Basis of Plant Load-Bearing Tests, Material Tests, and Inspection of Manufactured Pipe for Visual Defects and Imperfections*—Acceptability of the pipe in all diameters and classes produced in accordance with 7.1 or 7.2 shall be determined by the results of the three-edge bearing tests for either the load to produce a 0.3-mm crack, or at the option of the owner,

[2] *Annual Book of ASTM Standards*, Vol 01.04.
[3] *Annual Book of ASTM Standards*, Vol 04.02.
[4] *Annual Book of ASTM Standards*, Vol 04.01.
[5] *Annual Book of ASTM Standards*, Vol 04.05.



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							
2250	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 C 655M. 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.

the load to produce a 0.3-mm crack and the ultimate strength of the pipe; by such material tests as are required in 6.1, 6.2, and 6.4; by absorption tests on selected samples of concrete from the wall of the pipe; and by visual inspection of the finished pipe to determine its conformance with the accepted design and its freedom from defects.

5.1.2 *Acceptance on the Basis of Material Tests and Inspection of Manufactured Pipe for Defects and Imperfections*—Acceptability of the pipe in all diameters and classes produced in accordance with 7.1 or 7.2 shall be determined by the results of such material tests as are required in 6.1, 6.2, and 6.4; by crushing tests on concrete cores or cured concrete cylinders; by absorption tests on selected samples from the wall of the pipe; and by inspection of the finished pipe including amount and placement of reinforcement to determine its conformance with the accepted design and its freedom from defects.

5.1.3 When agreed upon 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, 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 C 150 or shall be portland blast-furnace slag cement or portland-pozzolan cement conforming to the requirements of Specification C 595, except that the pozzolan constituent in the Type IP portland-pozzolan cement shall be fly ash and shall not exceed 25 % by weight.

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

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

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 C 655M. 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 actual ultimate strength is greater than the minimum strength specified for nonreinforced pipe of equivalent diameters.

[E] As an alternative, single cage reinforcement may be used. The reinforcement area in square centimetres per linear metre shall be 4.2 for wall B and 3.4 for wall C.

6.2.3.1 Portland cement only,

6.2.3.2 Portland blast furnace slag cement only,

6.2.3.3 Portland pozzolan cement only, or

6.2.3.4 A combination of portland cement and fly ash.

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

6.4 *Admixtures and Blends*—Admixtures and blends may be used with the approval of the owner.

6.5 *Steel Reinforcement*—Reinforcement shall consist of wire conforming to Specification A 82 or Specification A 496 or of wire fabric conforming to Specification A 185 or Specification A 497 or of bars of Grade 300 steel conforming to Specification A 615/A 615M.

6.6 *Synthetic Fibers*—Collated fibrillated virgin polypropylene fibers may be used, at the manufacturer's option, in concrete pipe as a nonstructural manufacturing material. Only Type III synthetic fibers designed and manufactured specifically for use in

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] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]	Wall Thickness, mm	Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]	Wall Thickness, mm	Circular Reinforcement[B] Inner Cage	Circular Reinforcement[B] Outer Cage	Elliptical Reinforcement[C]
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 C 655M. 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 actual ultimate strength is greater than the minimum strength specified for nonreinforced pipe of equivalent diameters.

[E] As an alternative, single cage reinforcement may be used. The reinforcement area in square centimetres per linear metre shall be 6.4 for wall B and 4.2 for wall C.

concrete and conforming to the requirements of Specification C 1116 shall be accepted.

7. Design

7.1 *Design Tables*—The diameter, wall thickness, compressive strength of the concrete, and the area of the circumferential reinforcement shall be as prescribed for Classes I to V in Tables 1-5, except as provided in 7.2.

~~7.1.1 Footnotes to~~

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.

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 C 655M. 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.

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

7.2 *Modified and Special Designs* :

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

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

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 C 655M.
[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.

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.

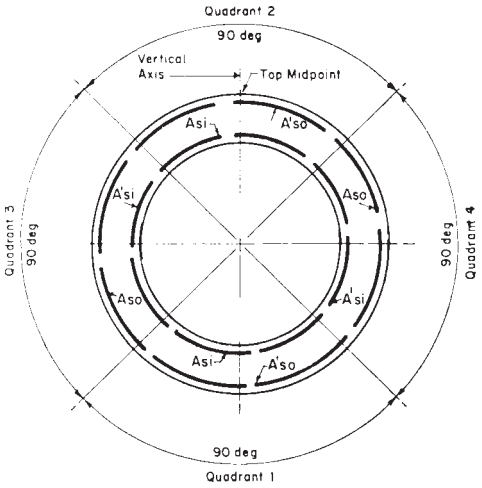
7.3 *Area*—In this specification, when the word area is not described by adjectives, such as cross-section or single wire, it shall be understood to be the cross-sectional area of reinforcement per unit lengths of pipe.

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 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.



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 Quadrants 1 and 2 not less than a distance equal to the wall thickness as specified in Tables 1-5.

FIG. 2 Quadrant Reinforcement

8.1.3 In pipe having elliptical reinforcement with wall thicknesses 63 mm 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 25 mm from the inner surface of the pipe at the vertical diameter and 25 mm from the outer surface of the pipe at the horizontal diameter. In pipe having elliptical reinforcement with wall thicknesses less than 63 mm, the protective covering of the concrete shall be 19 mm 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 100 mm for pipe up to and including pipe having a 100 mm wall thickness nor exceed the wall thickness for larger pipe, and shall in no case exceed 150 mm.

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 75 mm, 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 metre times the laying length of the pipe section. The minimum cover on the last circumferential near the spigot shoulder shall be 13 mm.

8.1.6.1 Where reinforcement is in the bell or spigot the minimum and cover on the last circumferential shall be 13 mm in the bell or 6 mm 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, pull tests of representative specimens shall develop at least 50 % of the minimum specified strength of the steel, and there shall be a minimum lap of 50 mm. For butt-welded splices in bars or wire, permitted only with helically wound cages, pull tests of representative specimens shall develop at least 75 % of the minimum specified strength of the steel.

8.2 *Longitudinal Reinforcement*—Each line of circumferential reinforcement shall be assembled into a cage that shall contain sufficient longitudinal bars or members, to maintain the reinforcement in shape and in position within the form to comply with

permissible variations in 8.1. The exposure of the ends of longitudinals, stirrups, or spacers that have been used to position the cages during the placement of the concrete shall not be a cause for rejection.

8.3 *Joint Reinforcement*—The length of the joint as used herein means the inside length of the bell or the outside length of the spigot from the shoulder to the end of the pipe section. The end distances or cover on the end circumferential shall apply to any point on the circumference of the pipe or joint. When convoluted reinforcement is used, these distances and reinforcement areas shall be taken from the points on the convolutions closest to the end of the pipe section. Unless otherwise permitted by the owner, the following requirements for joint reinforcement shall apply.

8.3.1 *Joint Reinforcement for Non-Rubber Gasket Joints*:

8.3.1.1 For pipe 900 mm and larger in diameter, either the bell or spigot shall contain circumferential reinforcement. This reinforcement shall be an extension of a wall cage, or may be a separate cage of at least the area per metre of that specified for the outer cage or one-half of that specified for single cage wall reinforcement, whichever is less.

8.3.1.2 Where bells or spigots require reinforcement, the maximum end cover on the last circumferential shall be one-half the length of the joint or 75 mm, whichever is less.

8.3.2 *Joint Reinforcement for Rubber Gasket Joints*:

8.3.2.1 For pipe 300 mm and larger in diameter, the bell ends shall contain circumferential reinforcement. This reinforcement shall be an extension of the outer cage or a single wall cage, whichever is less, or may be a separate cage of at least the same area per metre with longitudinals as required in 8.2. If a separate cage is used, the cage shall extend into the pipe with the last circumferential wire at least 25 mm past the inside shoulder where the pipe barrel meets the bell of the joint.

8.3.2.2 Where bells require reinforcement, the maximum end cover on the last circumferential shall be 50 mm.

9. Joints

9.1 The joints shall be of such design and the ends of the concrete pipe sections so formed that when the sections are laid together they will make a continuous line of pipe with a smooth interior free from appreciable irregularities in the flow line, all compatible with the permissible variations given in Section 13.

10. Manufacture

10.1 *Mixture*—The aggregates shall be sized, graded, proportioned, and mixed with such proportions of cementitious materials and water as will produce a homogeneous concrete mixture of such quality that the pipe will conform to the test and design requirements of this specification. All concrete shall have a water-cementitious materials ratio not exceeding 0.53 by weight. Cementitious materials shall be as specified in 6.2 and shall be added to the mix in a proportion not less than 280 kg/m^3 unless mix designs with a lower cementitious materials content demonstrate that the quality and performance of the pipe meet the requirements of this specification.

10.2 *Curing*—Pipe shall be subjected to any one of the methods of curing described in 10.2.1 to 10.2.4 or to any other method or combination of methods approved by the owner, that will give satisfactory results. The pipe shall be cured for a sufficient length of time so that the specified D-load is obtained when acceptance is based on 5.1.1 or so that the concrete will develop the specified compressive strength at 28 days or less when acceptance is based on 5.1.2.

10.2.1 *Steam Curing*—Pipe may be placed in a curing chamber, free of outside drafts, and cured in a moist atmosphere maintained by the injection of steam for such time and such temperature as may be needed to enable the pipe to meet the strength requirements. The curing chamber shall be so constructed as to allow full circulation of steam around the entire pipe.

10.2.2 *Water Curing*—Concrete pipe may be water-cured by covering with water saturated material or by a system of perforated pipes, mechanical sprinklers, porous hose, or by any other approved method that will keep the pipe moist during the specified curing period.

10.2.3 The manufacturer may, at his option, combine the methods described in 10.2.1 to 10.2.4 provided the required concrete compressive strength is attained.

10.2.4 A sealing membrane conforming to the requirements of Specification C 309 may be applied and should be left intact until the required strength requirements are met. The concrete at the time of application shall be within 6°C of the atmospheric temperature. All surfaces shall be kept moist prior to the application of the compounds and shall be damp when the compound is applied.

11. Physical Requirements

11.1 *Test Specimens*—The specified number of pipe required for the tests shall be furnished without charge by the manufacturer and shall be selected at random by the owner, and shall be pipe that would not otherwise be rejected under this specification. The selection shall be made at the point or points designated by the owner when placing the order.

11.2 *Number and Type of Test Required for Various Delivery Schedules*:

11.2.1 *Preliminary Tests for Extended Delivery Schedules* —An owner of pipe, whose needs require shipments at intervals over extended periods of time, shall be entitled to such tests, preliminary to delivery of pipe, as are required by the type of basis of acceptance specified by the owner in Section 5, of not more than three sections of pipe covering each size in which he is interested.

11.2.2 *Additional Tests for Extended Delivery Schedules* —After the preliminary tests described in 11.2.1, an owner shall be entitled to additional tests at such times as the owner may deem necessary, provided that the total number of pipe tested (including

preliminary tests) shall not exceed one pipe or 1 %, whichever is the greater, of each size of the pipe delivered.

11.3 *External Load Crushing Strength* :

11.3.1 The load to produce a 0.3-mm crack or the ultimate load, as determined by the three-edge-bearing method as described in the Test Methods C 497M shall be not less than that prescribed in Tables 1-5 for each respective class of pipe. Pipe that support the prescribed load to produce the 0.3–mm crack and do not show a wider crack shall be considered to have met that test requirement. It is not a requirement of this specification that the pipe be cracked or loaded to failure during these tests. Pipe that have been tested only to the formation of a 0.3-mm or lesser crack and that meet the 0.3-mm crack load requirements shall be accepted for use. Three-edge bearing test to ultimate load is not required for any class of pipe 1500 mm or less in diameter listed in Tables 1-5 provided all other requirements of this specification are met.

NOTE 3—As used in this specification, the 0.3-mm crack is a test criterion for pipe tested in three-edge bearing-test and is not intended as an indication of overstressed or failed pipe under installed conditions.

11.3.2 *Retests of Pipe Not Meeting the External Load Crushing Strength Requirements*—Pipe shall be considered as meeting the strength requirements when all test specimens conform to the strength requirements. Should any of the test specimens fail to meet the strength requirements, the manufacturer shall be allowed a retest on two additional specimens for each specimen that failed, and the pipe shall be acceptable only when all of the retest specimens meet the strength requirements.

CONCRETE TESTING

11.4 *Type of Specimen*—Compression tests determining concrete compressive strength may be made on either standard rodded concrete cylinders or concrete cylinders compacted and cured in like manner as the pipe, or on cores drilled from the pipe.

11.5 *Compression Testing of Cylinders* :

11.5.1 *Cylinder Production*—Cylinders shall be prepared in accordance with Section 11 of Test Methods C 497.

11.5.2 *Number of Cylinders*—Prepare no fewer than five test cylinders from a group (one day's production) of pipe sections.

11.5.3 *Acceptability on the Basis of Cylinder Test Results*:

11.5.3.1 When the compressive strengths of all cylinders tested for a group are equal to or greater than the required concrete strength, the compressive strength of concrete in the group of pipe sections shall be accepted.

11.5.3.2 When the average compressive strength of all cylinders tested is equal to or greater than the required concrete strength, and not more than 10 % of the cylinders tested have a compressive strength less than the required concrete strength, and no cylinder tested has a compressive strength less than 80 % of the required concrete strength, then the group shall be accepted.

11.5.3.3 When the compressive strength of the cylinders tested does not conform to the acceptance criteria stated in 11.5.3.1 or 11.5.3.2, the acceptability of the group shall be determined in accordance with the provisions of 11.6.

11.6 *Compression Testing of Cores* :

11.6.1 *Obtaining Cores*—Cores shall be obtained and prepared in accordance with Section 6 of Test Methods C 497.

11.6.2 *Number of Cores*—One core shall be taken from a pipe section selected at random from each day's production run of a single concrete strength.

11.7 *Acceptability on the Basis of Core Test Results*:

11.7.1 When the compressive strengths of cores tested for a group of pipe sections is equal to or greater than the required concrete strength, the compressive strength of the concrete for the group is acceptable. Concrete represented by core tests shall be considered acceptable if: (*1*) the average of three cores is equal to at least 85 % of the required strength, and (*2*) no single core is less than 75 % of the required strength.

11.7.2 If the compressive strength of the core tested is less than the required concrete strength, the pipe section from which that core was taken may be recored. If the compressive strength of the recore is equal to or greater than the required concrete compressive strength, the compressive strength of the concrete for the group is acceptable.

11.7.3 If the compressive strength of the recore is less than the required concrete strength, the pipe section from which the core was taken shall be rejected. Two pipe sections from the remainder of the group shall be selected at random and one core shall be taken from each pipe section. If the compressive strength of both cores is equal to or greater than the required concrete compressive strength, the concrete compressive strength of the remainder of the group shall be acceptable. If the compressive strength of either of the two cores tested is less than the required concrete compressive strength, then the remainder of the group shall be either rejected or, at the option of the manufacturer, each pipe section of the remainder shall be cored and accepted individually, and any of the pipe sections that have a core with less than the required concrete compressive strength shall be rejected.

11.8 *Plugging Core Holes*—Core holes shall be plugged and sealed by the manufacturer in a manner such that the pipe section will meet all of the requirements of this specification. Pipe sections so plugged and sealed shall be considered satisfactory for use.

11.9 *Absorption*—The absorption of a sample from the wall of the pipe, as determined in accordance with Test Methods C 497, shall not exceed 9 % of the dry mass for Method A or 8.5 % for Method B. Each Method A sample shall have a minimum mass of 1.0 kg, shall be free of visible cracks, and shall represent the full wall thickness of the pipe. When the initial absorption sample from a pipe fails to conform to this specification, the absorption test shall be made on another sample from the same pipe and the results of the retest shall be substituted for the original test results.

11.10 *Retests of Pipe*—When not more than 20 % of the concrete specimens fail to pass the requirements of this specification, the manufacturer may cull the project stock and may eliminate whatever quantity of pipe desired and shall mark those pipe so that

they will not be shipped. The required tests shall be made on the balance of the order and the pipe shall be accepted if they conform to the requirements of this specification.

11.11 *Test Equipment*—Every manufacturer furnishing pipe under this specification shall furnish all facilities and personnel necessary to carry out the tests described in Test Methods C 497M.

12. Permissible Variations

12.1 *Internal Diameter*—See Table 6. At the manufacturer's option the design diameter shall be the designated diameter of the converted English diameter. The internal diameter of 300 to 600 mm pipe shall vary not more than ± 1.5 % from the design diameter. The internal diameter for pipe larger than 600 mm shall not vary from the design diameter by more than ± 1 % of the design diameter or ± 10 mm, whichever is greater. Pipe sections that are intended to be jointed to each other shall be furnished with the same design diameter.

12.2 *Wall Thickness*—The wall thickness shall not vary more than shown in the design or specified wall by more than ± 5 % or 5 mm, whichever is greater. A specified wall thickness more than required in the design is not cause for rejection. Pipe having localized variations in wall thickness exceeding those specified above shall be accepted if the three-edge-bearing strength and minimum steel cover requirements are met.

12.3 *Length of Two Opposite Sides*—Variations in the laying length of two opposite sides of the pipe shall not be more than 6 mm for all sizes through 600-mm internal diameter, and not more than 10 mm/m of internal diameter for all sizes larger with a maximum of 16 mm in any length of pipe through 2100-mm internal diameter, and a maximum of 19 mm for 2250-mm internal diameter or larger, except where beveled end pipe for laying on curves is specified by the owner.

12.4 *Length of Pipe*—The underrun in length of a section of pipe shall not be more than 10 mm/m with a maximum of 13 mm in any length of pipe. Regardless of the underrun or overrun in any section of pipe, the end cover requirements of Section 8 and Section 12 shall apply.

12.5 *Position or Area of Reinforcement* :

12.5.1 *Position*—The maximum variation in the position of the reinforcement shall be ±10 % of the wall thickness or ±13 mm, whichever is greater. Pipe having variations in the position of the reinforcement exceeding those specified above shall be accepted if the three-edge-bearing strength requirements obtained on a representative specimen are met. In no case, however, shall the cover over the circumferential reinforcement be less than 6 mm as measured to the end of the spigot or 13 mm as measured to any other surface. The preceding minimum cover limitations do not apply to mating surfaces of non-rubber gasket joints or gasket grooves in rubber gasket joints. If convoluted reinforcement is used, the convoluted circumferential end wire may be at the end surface of the joint providing the alternate convolutions have at least 25 mm cover from the end surface of the joint.

12.5.2 *Area of Reinforcement*—Reinforcement will be considered as meeting the design requirements if the area, computed on the basis of nominal area of the wire or bars used, equals or exceeds the requirements of 7.1 or 7.2. Actual area of the reinforcing used may vary from the nominal area according to permissible variations of the standard specifications for the reinforcing. When inner cage and outer cage reinforcing is used, the inner cage nominal area may vary to the lower limit of 85 % of the elliptical

TABLE 6 Design Internal Diameters

Designated Diameter of Pipe, mm	Equivalent English Diameter, in.	Converted English Diameter, mm
300	12	305
375	15	381
450	18	457
525	21	533
600	24	610
675	27	686
750	30	762
825	33	838
900	36	914
1050	42	1067
1200	48	1219
1350	54	1372
1500	60	1524
1650	66	1676
1800	72	1829
1950	78	1981
2100	84	2134
2250	90	2286
2400	96	2438
2550	102	2591
2700	108	2743
2850	114	2896
3000	120	3048
3150	126	3200
3300	132	3353
3450	138	3505
3600	144	3658

nominal area and the outer cage nominal area may vary to the lower limit of 51 % of the elliptical nominal area provided that the total nominal area of the inner cage plus the outer cage shall not vary beyond the lower limit of 140 % of the elliptical nominal area.

13. Repairs

13.1 Pipe may be repaired, if necessary, because of imperfections in manufacture or damage during handling and will be acceptable if, in the opinion of the owner, the repaired pipe conforms to the requirements of this specification.

14. Inspection

14.1 The quality of materials, the process of manufacture, and the finished pipe shall be subject to inspection and approval by the owner.

15. Rejection

15.1 Pipe shall be subject to rejection on account of failure to conform to any of the specification requirements. Individual sections of pipe may be rejected because of any of the following:

15.1.1 Fractures or cracks passing through the wall, except for a single end crack that does not exceed the depth of the joint.

15.1.2 Defects that indicate proportioning, mixing, and molding not in compliance with 10.1 or surface defects indicating honeycombed or open texture that would adversely affect the function of the pipe.

15.1.3 The ends of the pipe are not normal to the walls and center line of the pipe, within the limits of variations given in 12.3 and 12.4.

15.1.4 Damaged or cracked ends where such damage would prevent making a satisfactory joint.

15.1.5 Any continuous crack having a surface width of 0.3 mm or more and extending for a length of 300 mm or more, regardless of position in the wall of the pipe.

16. Product Marking

16.1 The following information shall be legibly marked on each section of pipe:

16.1.1 The pipe class and specification designation.

16.1.2 The date of manufacture.

16.1.3 The name or trademark of the manufacturer, and

16.1.4 Identification of plant.

16.2 One end of each section of pipe with elliptical or quadrant reinforcement shall be clearly marked during the process of manufacturing or immediately thereafter, on the inside and the outside of opposite walls along the minor axis of the elliptical reinforcing or along the vertical axis for quadrant reinforcing.

16.3 Markings shall be indented on the pipe section or painted thereon with waterproof paint.

17. Keywords

17.1 circular pipe; culvert; D-load; pipe; reinforced concrete; sewer pipe; storm drain