Designation: C 76M – 00
METRIC

# 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:*

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

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

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

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

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

C 33 Specification for Concrete Aggregates[3]

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens[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, 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

[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.

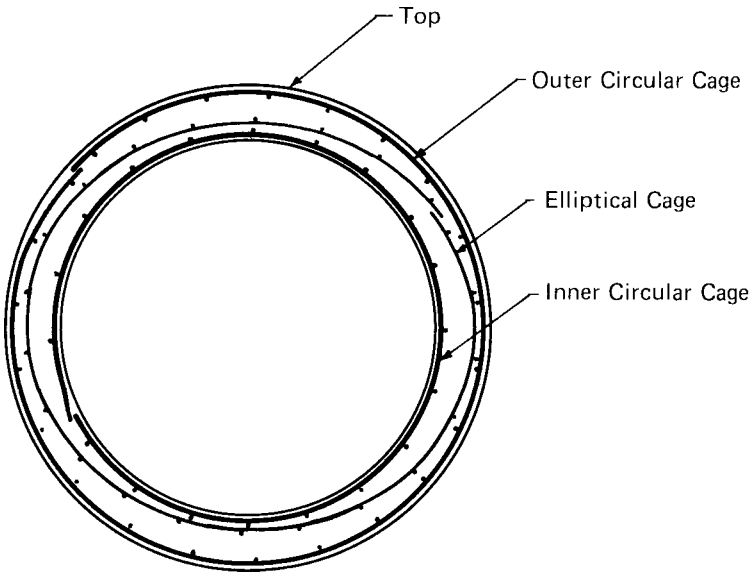
Current edition approved June 10, 2000. Published September 2000. Originally published as C 76M–80. Last previous edition C 76M–99a.

[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**

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:

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 wherein the proportion of fly ash is between 5 and 25 % by weight of total cementitious material (portland cement plus 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 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 the tables herein are intended to be amplifications of tabulated requirements and are to be considered applicable and binding as if they were contained in the

**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<br>Plus Elliptical 8.0 | 238 | 11.4 | 6.8 | Inner Circular 4.6<br>Plus Elliptical 6.8 |
| 2700 | 225 | 14.4 | 8.6 | Inner Circular 5.8<br>Plus Elliptical 8.6 | 250 | 12.9 | 7.7 | Inner Circular 5.2<br>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.



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 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

**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, cm²/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<br>Plus Elliptical 9.7 | 238 | 14.4 | 8.6 | Inner Circular 5.8<br>Plus Elliptical 8.6 | 257 | 13.1 | 7.9 | Inner Circular 5.2<br>Plus Elliptical 7.9 |
| 2700 | 225 | 18.0 | 10.8 | Inner Circular 7.2<br>Plus Elliptical 10.8 | 250 | 16.1 | 9.7 | Inner Circular 6.4<br>Plus Elliptical 9.7 | 269 | 14.8 | 8.9 | Inner Circular 5.9<br>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.

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.

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.

**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<br>Plus Elliptical 8.9 |
| 2550 | 213 | 21.8 | 13.1 | Inner Circular 8.7<br>Plus Elliptical 13.1 | 238 | 19.1 | 11.5 | Inner Circular 7.6<br>Plus Elliptical 11.5 | 257 | 17.6 | 10.6 | Inner Circular 7.0<br>Plus Elliptical 10.6 |
| 2700 | 225 | 25.8 | 15.5 | Inner Circular 10.3<br>Plus Elliptical 15.5 | 250 | 22.9 | 13.7 | Inner Circular 9.2<br>Plus Elliptical 13.7 | 269 | 21.0 | 12.6 | Inner Circular 8.4<br>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.

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

**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.



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