



Designation: C76M – 10

# Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe (Metric)<sup>1</sup>

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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

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

1.2 This specification is the SI companion to Specification C76.

NOTE 1—This specification is a manufacturing and purchase specification only, and does not include requirements for bedding, backfill, or the relationship between field load condition and the strength classification of pipe. However, experience has shown that the successful performance of this product depends upon the proper selection of the class of pipe, type of bedding and backfill, controlled manufacture in the plant, and care and installation conforms to the construction specifications. The owner of the reinforced concrete pipe specified herein is cautioned that he must correlate the field requirements with the class of pipe specified and provide inspection at the construction site.

NOTE 2—Attention is called to the specification for reinforced concrete D-load culvert, storm drain, and sewer pipe (ASTM Designation C655M).

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

- A36/A36M Specification for Carbon Structural Steel
- A82/A82M Specification for Steel Wire, Plain, for Concrete Reinforcement
- A185/A185M Specification for Steel Welded Wire Reinforcement, Plain, for Concrete
- A496/A496M Specification for Steel Wire, Deformed, for Concrete Reinforcement
- A497/A497M Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete
- A615/A615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

- A706/A706M Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
- C33 Specification for Concrete Aggregates
- C150 Specification for Portland Cement
- C260 Specification for Air-Entraining Admixtures for Concrete
- C309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete
- C494/C494M Specification for Chemical Admixtures for Concrete
- C497M Test Methods for Concrete Pipe, Manhole Sections, or Tile [Metric]
- C595 Specification for Blended Hydraulic Cements
- C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
- C655M Specification for Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe (Metric)
- C822 Terminology Relating to Concrete Pipe and Related Products
- C989 Specification for Slag Cement for Use in Concrete and Mortars
- C1017/C1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete
- C1116 Specification for Fiber-Reinforced Concrete and Shotcrete

## 3. Terminology

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

## 4. Classification

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

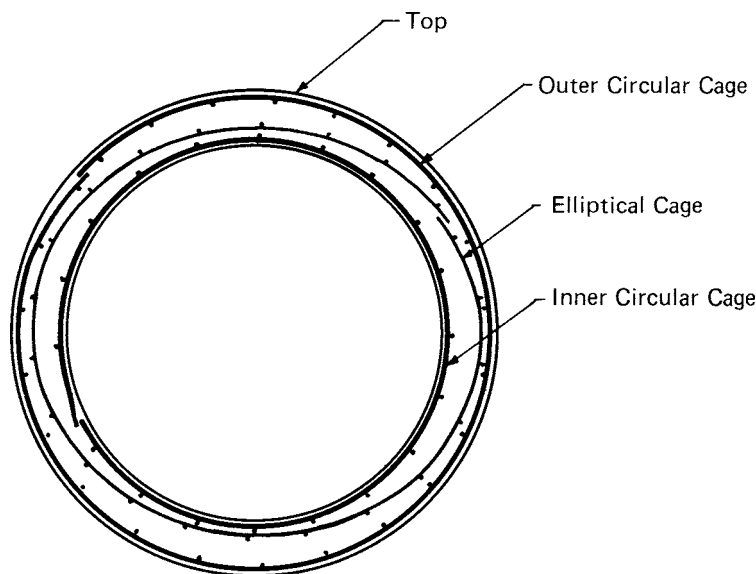
## 5. Basis of Acceptance

5.1 Unless otherwise designated by the owner at the time of, or before placing an order, there are two separate and alternative bases of acceptance. Independent of the method of

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



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

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

**FIG. 1 Triple Cage Reinforcement**

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, and

water, in which steel has been embedded in such a manner that the steel and concrete act together.

### 6.2 Cementitious Materials:

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

6.2.2 *Ground Granulated Blast-Furnace Slag*—GGBFS shall conform to the requirements of Grade 100 or 120 of Specification C989.

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

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

6.2.4.1 Portland cement only,

6.2.4.2 Portland blast furnace slag cement only,

6.2.4.3 Slag modified Portland cement only,

6.2.4.4 Portland pozzolan cement only,

6.2.4.5 A combination of Portland cement and ground granulated blast-furnace slag,

6.2.4.6 A combination of Portland cement and fly ash, or

6.2.4.7 A combination of Portland cement, ground granulated blast-furnace slag (not to exceed 25 % of the total cementitious weight) and fly ash (not to exceed 25 % of the total cementitious weight).

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

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

**TABLE 1 Design Requirements for Class I Reinforced Concrete Pipe<sup>A</sup>**

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                      |            | D-load to produce the ultimate load       |                             |                                     |            |   |  |
|----------------------------------|-----------------------------|---|------------|---|-----------------------------|-------------------------------------|------------|---|--|
|                                  |                             | 40.0  |            | 60.0                                      |                             |                                     |            |   |  |
|                                  |                             | Reinforcement, cm <sup>2</sup> /linear m of pipe wall |            |   |                             |                                     |            |   |  |
| Internal Designated Diameter, mm | Wall A                      |   |            |   | Wall B                      |                                     |            |   |  |
|                                  | Concrete Strength, 27.6 MPa |   |            |   | Concrete Strength, 27.6 MPa |                                     |            |   |  |
|                                  | Wall Thickness, mm          | Circular Reinforcement <sup>B</sup>                   |            | Elliptical Reinforcement <sup>C</sup>     | Wall Thickness, mm          | Circular Reinforcement <sup>B</sup> |            | Elliptical Reinforcement <sup>C</sup>     |  |
|                                  |                             | 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<br>8.0 | 238                         | 11.4                                | 6.8        | Inner Circular Plus Elliptical 4.6<br>6.8 |  |
| 2700                             | 225                         | 14.4  | 8.6        | Inner Circular Plus Elliptical 5.8<br>8.6 | 250                         | 12.9                                | 7.7        | Inner Circular Plus Elliptical 5.2<br>7.7 |  |
| 2850                             | A                           | ...   | ...        | ...                                       | A                           | ...                                 | ...        | ...                                       |  |
| 3000                             | A                           | ...   | ...        | ...                                       | A                           | ...                                 | ...        | ...                                       |  |
| 3150                             | A                           | ...   | ...        | ...                                       | A                           | ...                                 | ...        | ...                                       |  |
| 3300                             | A                           | ...   | ...        | ...                                       | A                           | ...                                 | ...        | ...                                       |  |
| 3450                             | A                           | ...   | ...        | ...                                       | A                           | ...                                 | ...        | ...                                       |  |
| 3600                             | A                           | ...   | ...        | ...                                       | A                           | ...                                 | ...        | ...                                       |  |

<sup>A</sup> 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.

<sup>B</sup> 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.

<sup>C</sup> Elliptical and quadrant steel must be held in place by means of holding rods, chairs, or other positive means throughout the entire casting operation.

6.4.1 Air-entraining admixture conforming to Specification C260;

6.4.2 Chemical admixture conforming to Specification C494/C494M;

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

6.4.4 Chemical admixture or blend approved by the owner.

6.5 *Steel Reinforcement*—Reinforcement shall consist of wire conforming to Specification A82/A82M or Specification A496/A496M; or of wire reinforcement conforming to Specification A185/A185M or Specification A497/A497M; or of bars conforming to Specification A36/A36M, Specification A615/A615M Grade 40 or 60, or Specification A706/A706M Grade 60.

6.6 *Synthetic Fibers*—Collated fibrillated virgin polypropylene fibers may be used, at the manufacturer's option, in concrete pipe as a nonstructural manufacturing material. Only Type III synthetic fibers designed and manufactured specifically for use in concrete and conforming to the requirements of Specification C1116 shall be accepted.

**7. Design**

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

7.1.1 The reinforcement as presented in the tables herein allows single circular cage reinforcement or separate inner and outer circular cage reinforcement or single elliptical cage reinforcement or a combination thereof.

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

7.2 *Modified and Special Designs:*

7.2.1 If permitted by the owner the manufacturer may request approval by the owner of modified designs that differ from the designs in; or special designs for sizes and loads beyond those shown in Tables 1-5, 7.1, or special designs for pipe sizes that do not have steel reinforcement areas shown in Tables 1-5.

**TABLE 2 Design Requirements for Class II Reinforced Concrete Pipe<sup>A</sup>**

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 <sup>2</sup> /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 <sup>B</sup> |            | Elliptical Reinforcement <sup>C</sup> | Wall Thickness, mm          | Circular Reinforcement <sup>B</sup> |            | Elliptical Reinforcement <sup>C</sup> | Wall Thickness, mm             | Circular Reinforcement <sup>B</sup> |            | Elliptical Reinforcement <sup>C</sup> |     |                                |            |
| Inner Cage                       |   | Outer Cage                          | Inner Cage |                                       |                             | Outer Cage                          | Inner Cage |                                       |                                | Outer Cage                          | Inner Cage | Outer Cage                            |     |                                |            |
| 300                              | 44  | 1.5 <sup>D</sup>                    | ...        | ...                                   | 50                          | 1.5 <sup>D</sup>                    | ...        | ...                                   | 69                             | 1.5 <sup>D</sup>                    | ...        | ...                                   |     |                                |            |
| 375                              | 47  | 1.5 <sup>D</sup>                    | ...        | ...                                   | 57                          | 1.5 <sup>D</sup>                    | ...        | ...                                   | 75                             | 1.5 <sup>D</sup>                    | ...        | ...                                   |     |                                |            |
| 450                              | 50  | 1.5 <sup>D</sup>                    | ...        | ...                                   | 63                          | 1.5 <sup>D</sup>                    | ...        | 1.5 <sup>D</sup>                      | 82                             | 1.5 <sup>D</sup>                    | ...        | 1.5 <sup>D</sup>                      |     |                                |            |
| 525                              | 57  | 2.5                                 | ...        | 2.1                                   | 69                          | 1.5 <sup>D</sup>                    | ...        | 1.5 <sup>D</sup>                      | 88                             | 1.5 <sup>D</sup>                    | ...        | 1.5 <sup>D</sup>                      |     |                                |            |
| 600                              | 63  | 2.8                                 | ...        | 2.3                                   | 75                          | 1.5 <sup>D</sup>                    | ...        | 1.5 <sup>D</sup>                      | 94                             | 1.5 <sup>D</sup>                    | ...        | 1.5 <sup>D</sup>                      |     |                                |            |
| 675                              | 66  | 3.2                                 | ...        | 2.8                                   | 82                          | 2.8                                 | ...        | 2.3                                   | 100                            | 1.5 <sup>D</sup>                    | ...        | 1.5 <sup>D</sup>                      |     |                                |            |
| 750                              | 69  | 3.2                                 | ...        | 3.0                                   | 88                          | 3.0                                 | ...        | 2.5                                   | 106                            | 1.5 <sup>D</sup>                    | ...        | 1.5 <sup>D</sup>                      |     |                                |            |
| 825                              | 72  | 3.4                                 | ...        | 3.2                                   | 94                          | 3.2                                 | ...        | 2.8                                   | 113                            | 1.5 <sup>D</sup>                    | ...        | 1.5 <sup>D</sup>                      |     |                                |            |
| 900                              | 75  | 3.0                                 | 1.8        | 3.2                                   | 100 <sup>E</sup>            | 2.5                                 | 1.5        | 2.8                                   | 119 <sup>E</sup>               | 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 Plus Elliptical        | 6.4<br>9.7                  | 238                                 | 14.4       | 8.6                                   | Inner Circular Plus Elliptical | 5.8<br>8.6                          | 257        | 13.1                                  | 7.9 | Inner Circular Plus Elliptical | 5.2<br>7.9 |
| 2700                             | 225   | 18.0                                | 10.8       | Inner Circular Plus Elliptical        | 7.2<br>10.8                 | 250                                 | 16.1       | 9.7                                   | Inner Circular Plus Elliptical | 6.4<br>9.7                          | 269        | 14.8                                  | 8.9 | Inner Circular Plus Elliptical | 5.9<br>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          | ...                                   | ... | ...                            | ...        |

<sup>A</sup> 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.

<sup>B</sup> 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.

<sup>C</sup> Elliptical and quadrant steel must be held in place by means of holding rods, chairs, or other positive means throughout the entire casting operation.

<sup>D</sup> 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.

<sup>E</sup> 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.

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.

**TABLE 3 Design Requirements for Class III Reinforced Concrete Pipe<sup>A</sup>**

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.

| Internal Designated Diameter, mm | Reinforcement, cm <sup>2</sup> /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 <sup>B</sup> |            | Elliptical Reinforcement <sup>C</sup>       | Wall Thickness, mm          | Circular Reinforcement <sup>B</sup> |              | Elliptical Reinforcement <sup>C</sup>      | Wall Thickness, mm          | Circular Reinforcement <sup>B</sup> |      | Elliptical Reinforcement <sup>C</sup>      |
| Inner Cage                       |   | Outer Cage                          | Inner Cage |   |                             | Outer Cage                          | Inner Cage   |  |                             | Outer Cage                          |      |  |
| 300                              | 44  | 1.5 <sup>D</sup>                    | ...        | ...   | 50                          | 1.5 <sup>D</sup>                    | <sup>D</sup> | ...  | 69                          | 1.5 <sup>D</sup>                    | ...  | ...  |
| 375                              | 47  | 1.5 <sup>D</sup>                    | ...        | ...   | 57                          | 1.5 <sup>D</sup>                    | ...          | ...  | 75                          | 1.5 <sup>D</sup>                    | ...  | ...  |
| 450                              | 50  | 1.5 <sup>D</sup>                    | ...        | 1.5 <sup>D</sup>                            | 63                          | 1.5 <sup>D</sup>                    | ...          | 1.5 <sup>D</sup>                           | 82                          | 1.5 <sup>D</sup>                    | ...  | 1.5 <sup>D</sup>                           |
| 525                              | 57  | 3.0                                 | ...        | 2.3   | 69                          | 1.5 <sup>D</sup>                    | ...          | 1.5 <sup>D</sup>                           | 88                          | 1.5 <sup>D</sup>                    | ...  | 1.5 <sup>D</sup>                           |
| 600                              | 63  | 3.6                                 | ...        | 3.0   | 75                          | 1.5 <sup>D</sup>                    | ...          | 1.5 <sup>D</sup>                           | 94                          | 1.5 <sup>D</sup>                    | ...  | 1.5 <sup>D</sup>                           |
| 675                              | 66  | 3.8                                 | ...        | 3.4   | 82                          | 3.4                                 | ...          | 3.0  | 100                         | 1.7                                 | ...  | 1.5 <sup>D</sup>                           |
| 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 <sup>E</sup>            | 3.6                                 | 2.2          | 4.0  | 119 <sup>E</sup>            | 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      |   |                                     |            |   |                             |                                     |              |  |                             |                                     |      |  |
| 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                           | ...                                 | ...  | ...  |

<sup>A</sup> 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.

<sup>B</sup> 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.

<sup>C</sup> Elliptical and quadrant steel must be held in place by means of holding rods, chairs, or other positive means throughout the entire casting operation.

<sup>D</sup> 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.

<sup>E</sup> 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.

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

**TABLE 4 Design Requirements for Class IV Reinforced Concrete Pipe<sup>A</sup>**

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 <sup>2</sup> /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 <sup>B</sup> |            | Elliptical Reinforcement <sup>C</sup> | Wall Thickness, mm          | Circular Reinforcement <sup>B</sup> |            | Elliptical Reinforcement <sup>C</sup> | Wall Thickness, mm          | Circular Reinforcement <sup>B</sup> |      | Elliptical Reinforcement <sup>C</sup> |
| Inner Cage                       |   | Outer Cage                          | Inner Cage |                                       |                             | Outer Cage                          | Inner Cage |                                       |                             | Outer Cage                          |      |                                       |
| 300                              | 44  | 3.2                                 | ...        | ...                                   | 50                          | 1.5                                 | ...        | ...                                   | 69                          | 1.5 <sup>D</sup>                    | ...  | ...                                   |
| 375                              | 47  | 3.4                                 | ...        | ...                                   | 57                          | 2.1                                 | ...        | ...                                   | 75                          | 1.5 <sup>D</sup>                    | ...  | ...                                   |
| 450                              | 50  | 3.6                                 | ...        | 3.2                                   | 63                          | 3.0                                 | ...        | 2.3                                   | 82                          | 1.5 <sup>D</sup>                    | ...  | 1.5 <sup>D</sup>                      |
| 525                              | 57  | 4.9                                 | ...        | 4.4                                   | 69                          | 4.2                                 | ...        | 3.6                                   | 88                          | 1.5 <sup>D</sup>                    | ...  | 1.5 <sup>D</sup>                      |
| 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                             | A   | ...                                 | ...        | ...                                   | 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                           | ...                                 | ...  | ...                                   |
| 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                           | ...                                 | ...  | ...                                   |

<sup>A</sup> 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.

<sup>B</sup> 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.

<sup>C</sup> Elliptical and quadrant steel must be held in place by means of holding rods, chairs, or other positive means throughout the entire casting operation.

<sup>D</sup> For these classes and sizes, the minimum practical steel reinforcement is specified.

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.

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