Designation: ~~C507 – 12a~~ C507 – 13

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

This standard is issued under the fixed designation C507; 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 elliptically shaped concrete pipe to be used for the conveyance of sewage, industrial wastes, and storm water, and for the construction of culverts.

1.2 Pipe designed for placement with the major axis horizontal shall be designated as "Horizontal Elliptical Pipe." Pipe designed for placement with the major axis vertical shall be designated as "Vertical Elliptical Pipe."

1.3 This specification is the inch-pound companion to Specification C507M; therefore, no SI equivalents are presented in the specification.

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, and care that the 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.

2. Referenced Documents

2.1 *ASTM Standards*:[2]

A36/A36M Specification for Carbon Structural Steel
A615/A615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
A706/A706M Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
A1064/A1064M Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
C33 Specification for Concrete Aggregates
C150 Specification for Portland Cement
C260 Specification for Air-Entraining Admixtures for Concrete
C309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete
C494/C494M Specification for Chemical Admixtures for Concrete
C497 Test Methods for Concrete Pipe, Manhole Sections, or Tile
C595 Specification for Blended Hydraulic Cements
C618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
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.

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[1] This specification is under the jurisdiction of ASTM Committee C13 on Concrete Pipe and is the direct responsibility of Subcommittee C13.02 on Reinforced Sewer and Culvert Pipe.

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

4. Classification

4.1 Pipe manufactured according to this specification shall be of five classes each for horizontal elliptical and vertical elliptical pipe with identification as follows:

Horizontal Elliptical Pipe	Vertical Elliptical Pipe
Class HE-A	Class VE-II
Class HE-I	Class VE-III
Class HE-II	Class VE-IV
Class HE-III	Class VE-V
Class HE-IV	Class VE-VI

4.2 The strength requirements for horizontal elliptical pipe are prescribed in Table 1 and for vertical elliptical pipe are prescribed in Table 2.

5. Basis of Acceptance

5.1 Unless otherwise designated by the owner at the time of, or before, placing an order, there are two separate and alternative bases of acceptance. Independent of the method of acceptance, the pipe shall be designed to meet both the 0.01-in. crack and ultimate strength requirements.

5.1.1 *Acceptance on 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,

TABLE 1 Design Requirements for Horizontal Elliptical (HE) Pipe[A]

NOTE 1—The test load in pounds per linear foot equals D-load × inside span in feet.

NOTE 2—Single cage reinforcement, providing tension steel at the top, bottom, and springline, shall be permitted instead of double cage reinforcement. The area of such reinforcement shall be 112 % of the tabulated inner cage area.

NOTE 3—An inner and outer cage plus quadrant mats shall be permitted instead of double cage reinforcement. The area of such reinforcement shall be in accordance with Fig. 1.

NOTE 4—An inner and outer cage plus a middle cage shall be permitted instead of double cage reinforcement. The area of such reinforcement shall be in accordance with Fig. 2.

Designated Diameter, Equivalent Round Size, in.	Designated Rise, in. × Span, in.	Minimum Wall Thickness, in.	Reinforcement, in.^{2}/linear ft									
			Class HE-A		Class HE-I		Class HE-II		Class HE-III		Class HE-IV	
			D-Loads									
			0.01 = 600 Ult = 900		0.01 = 800 Ult = 1200		0.01 = 1000 Ult = 1500		0.01 = 1350 Ult = 2000		0.01 = 2000 Ult = 3000	
			In Cage	Out Cage	In Cage	Out Cage	In Cage	Out Cage	In Cage	Out Cage	In Cage	Out Cage
18	14 × 23	2¾	0.08	. . .	0.11	. . .	0.14	. . .	0.19	. . .	0.27	. . .
24	19 × 30	3¼	0.11	. . .	0.15	. . .	0.19	. . .	0.26	. . .	0.39	. . .
27	22 × 34	3½	0.14	. . .	0.18	. . .	0.23	. . .	0.31	. . .	0.45	. . .
30	24 × 38	3¾	0.10	0.10	0.12	0.12	0.17	0.17	0.23	0.23	0.34	0.34
33	27 × 42	3¾	0.12	0.12	0.17	0.17	0.21	0.21	0.27	0.27	0.41	0.41
36	29 × 45	4½	0.11	0.11	0.15	0.15	0.19	0.19	0.26	0.26	0.39	0.39
39	32 × 49	4¾	0.12	0.12	0.17	0.17	0.21	0.21	0.29	0.29	0.44	0.44
42	34 × 53	5	0.15	0.15	0.20	0.20	0.24	0.24	0.33	0.33	0.50	0.50
48	38 × 60	5½	0.17	0.17	0.23	0.23	0.27	0.27	0.39	0.39	. . .	. .
54	43 × 68	6	0.20	0.20	0.27	0.27	0.34	0.34	0.45	0.45	. . .	. . ..
60	48 × 76	6½	0.24	0.24	0.32	0.32	0.40	0.40	0.53	0.53	. . .	. . .
66	53 × 83	7	0.27	0.27	0.36	0.36	0.45	0.45	0.60	0.60	. . .	. . .
72	58 × 91	7½	0.31	0.31	0.41	0.41	0.52	0.52	0.70	0.70	. . .	. . .
78	63 × 98	8	0.34	0.34	0.45	0.45	0.56	0.56	0.78	0.78	. . .	. . .
84	68 × 106	8½	0.38	0.38	0.50	0.50	0.63	0.63	0.88	0.88	. . .	. . .
90	72 × 113	9	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
96	77 × 121	9½	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
102	82 × 128	9¾	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
108	87 × 136	10	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
114	92 × 143	10½	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
120	97 × 151	11	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
132	106 × 166	12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
144	116 × 180	13	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Concrete strength[B], psi			4000		4000		4000		18 to 66 in. 4000 / 72 to 84 in. 5000		4000	

[A] For sizes and loads beyond those shown in this table, pipe designs are available that make use of one or a combination of the following: shear steel, multiple cages, or thicker walls in accordance with the provisions of 7.3.

[B] Concrete strength for designs with reinforcement tabulated. For modified or special designs, see 7.3.

TABLE 2 Design Requirements for Vertical Elliptical Pipe[A]

NOTE 1—Test load in pounds per linear foot equals D-load × inside span in feet.

NOTE 2—An inner and outer cage plus quadrant mats shall be permitted instead of double cage reinforcement. The area of such reinforcement shall be in accordance with Fig. 3.

NOTE 3—Single cage reinforcement, providing tension steel at the top, bottom, and springline, shall be permitted instead of double cage reinforcement. The area of such reinforcement shall be 112 % of the tabulated inner cage area.

NOTE 4—An inner and outer cage plus a middle cage shall be permitted instead of double cage reinforcement. The area of such reinforcement shall be in accordance with Fig. 4.

Designated Diameter, Equivalent Round Size, in.	Designated Rise, in. × Span, in.	Minimum Wall Thickness, in.	Reinforcement, in.²/linear ft									
			Class VE-II		Class VE-III		Class VE-IV		Class VE-V		Class VE-VI	
			D-Loads									
			0.01 = 1000 Ult = 1500		0.01 = 1350 Ult = 2000		0.01 = 2000 Ult = 3000		0.01 = 3000 Ult = 3750		0.01 = 4000 Ult = 5000	
			In Cage	Out Cage	In Cage	Out Cage	In Cage	Out Cage	In Cage	Out Cage	In Cage	Out Cage
36	45 × 29	4½	0.08	0.05	0.11	0.07	0.16	0.10	0.23	0.14	0.31	0.19
39	49 × 32	4¾	0.09	0.05	0.12	0.07	0.18	0.11	0.26	0.16	0.35	0.21
42	53 × 34	5	0.10	0.06	0.12	0.08	0.20	0.12	0.29	0.17	0.38	0.23
48	60 × 38	5½	0.11	0.07	0.15	0.09	0.21	0.12	0.33	0.20	0.44	0.26
54	68 × 43	6	0.12	0.08	0.18	0.11	0.27	0.16	0.40	0.24	0.53	0.32
60	76 × 48	6½	0.16	0.10	0.21	0.12	0.31	0.19	0.47	0.27	. . .	. . .
66	83 × 53	7	0.18	0.11	0.24	0.15	0.36	0.21	0.55	0.33	. . .	. . .
72	91 × 58	7½	0.21	0.12	0.27	0.17	0.41	0.24	. . .	. . .	. . .	. . .
78	98 × 63	8	0.23	0.14	0.31	0.19	0.47	0.27	. . .	. . .	. . .	. . .
84	106 × 68	8½	0.26	0.16	0.35	0.21	0.53	0.32	. . .	. . .	. . .	. . .
90	113 × 72	9	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
96	121 × 77	9½	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
102	128 × 82	9¾	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
108	136 × 87	10	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
114	143 × 92	10½	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
120	151 × 97	11	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
132	166 × 106	12	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
144	180 × 116	13	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Concrete strength[B], psi			4000		4000		4000		5000		6000	

[A] For sizes and loads beyond those shown in this table, pipe designs are available which make use of one or a combination of the following: shear steel, multiple cages, or thicker walls in accordance with the provisions of 7.3.
[B] Concrete strength for designs with reinforcement tabulated. For modified or special designs, see 7.3.

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 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 6.2, 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 by the owner and the 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 they conform to the requirements as indicated by the specified tests.

6. Materials

6.1 The aggregate shall be so sized, graded, proportioned, and mixed with such proportions of portland cement, blended hydraulic cement, or portland cement and supplementary cementing materials, or admixtures, if used, or a combination thereof, and water to produce a homogeneous concrete mixture of such quality that the pipe will conform to the test and design requirements of this specification. In no case, however, shall the proportion of portland cement, blended hydraulic cement, or a combination of portland cement and supplementary cementing materials be less than 470 lb/yd^3.

6.2 *Cementitious Materials:*

6.2.1 *Cement*—Cement shall conform to the requirements 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)*—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.~~slag, and fly ash.

6.2.4.8 A combination of portland pozzolan cement and fly ash.

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

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

6.4.1 Air-entraining admixture conforming to Specification C260;

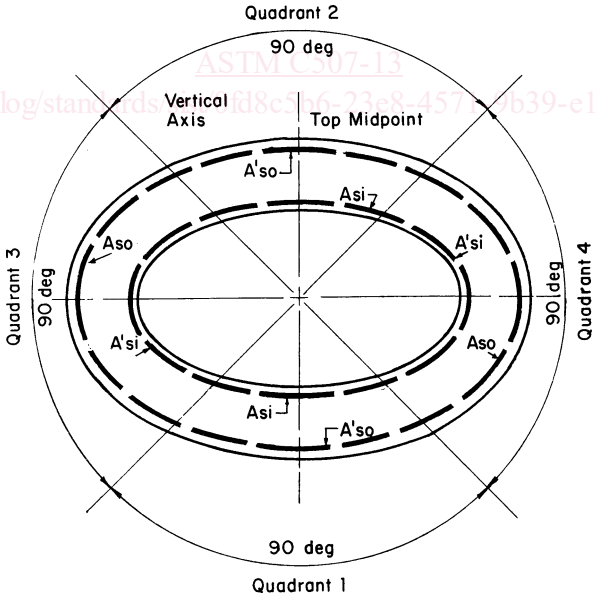
6.4.2 Chemical admixture conforming to Specification C494/C494M;

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

6.4.4 Chemical admixture or blend approved by the owner.

6.5 *Steel Reinforcement*—Reinforcement shall conform to the requirements of Specification A1064/A1064M, or bars conforming to Specification A36/A36M, Specification A615/A615M Grade 40 or 60, or Specification A706/A706M Grade 60. For helically wound cages only, weld shear tests are not required.

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.



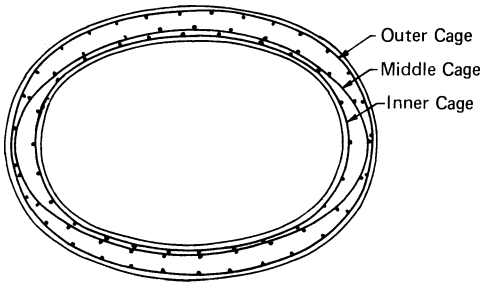
NOTE 1—The total reinforcement area (Asi) of the inner cage plus the quadrant mat in Quadrants 1 and 2 shall not be less than that specified for the inner cage in Table 1.

NOTE 2—The total reinforcement area (Aso) of the outer cage plus the quadrant mat in Quadrants 3 and 4 shall not be less than that specified for the outer cage in Table 1.

NOTE 3—The reinforcement area (A'si) of the inner cage in Quadrants 3 and 4 shall be not less than 25 % of that specified for the inner cage in Table 1.

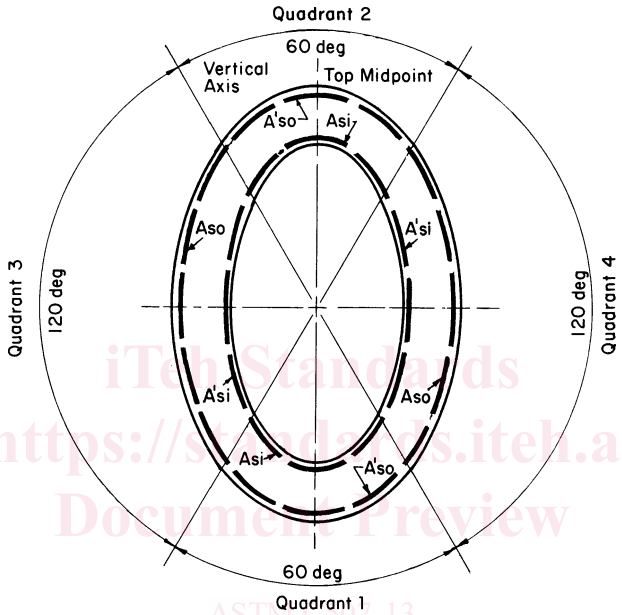
NOTE 4—The reinforcement area (A'so) of the outer cage in Quadrants 1 and 2 shall be not less than 25 % of that specified for the outer cage in Table 1.

FIG. 1 Quadrant Reinforcement, Horizontal Elliptical Pipe



NOTE 1—The total reinforcement area of the inner cage plus the middle cage shall not be less than that specified for the inner cage in Table 1.
NOTE 2—The total reinforcement area of the outer cage plus the middle cage shall not be less than that specified for the outer cage in Table 1.

FIG. 2 Horizontal Elliptical Pipe



NOTE 1—The total reinforcement area (Asi) of the inner cage plus the quadrant mat in Quadrants 1 and 2 shall not be less than that specified for the inner cage in Table 2.

NOTE 2—The total reinforcement area (Aso) of the outer cage plus the quadrant mat in Quadrants 3 and 4 shall not be less than that specified for the outer cage in Table 2.

NOTE 3—The reinforcement area (A'si) of the inner cage in Quadrants 3 and 4 shall be not less than 25 % of that specified for the inner cage in Table 2.

NOTE 4—The reinforcement area (A'so) of the outer cage in Quadrants 1 and 2 shall be not less than 25 % of that specified for the outer cage in Table 2.

FIG. 3 Quadrant Reinforcement, Vertical Elliptical Pipe

7. Design

7.1 *Size and Shape*—The standard sizes of elliptical pipe shall be as listed in Table 1 and Table 2. The internal shape for each size pipe shall be defined by the internal dimensions shown in Fig. 5, subject to the permissible variations of 12.1.

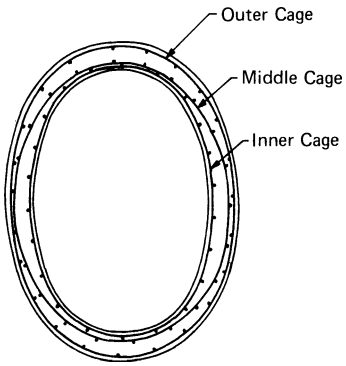
7.2 *Design Tables*—The wall thickness, compressive strength of concrete, and the area of circumferential reinforcement shall be as prescribed in Table 1 and Table 2, subject to the provisions of 7.3 and Sections 11 and 12.

7.2.1 Footnotes to the tables herein are intended to be amplifications of the tabulated requirements and are to be considered applicable and binding as if they were contained in the body of the specification.

7.3 *Modified and Special Designs:*

7.3.1 If permitted by the owner, the manufacturer may request approval by the owner of modified designs which differ from the designs in this Section 7; or special designs for sizes and loads beyond those shown in Table 1 and Table 2; or special designs for pipe sizes that do not have steel reinforcement areas shown in Table 1 and Table 2.

7.3.2 Such modified and special designs shall be based on rational or empirical evaluations of the ultimate strength and cracking behavior of pipe and shall fully describe to the owner any deviations from the requirements of this section. 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.



NOTE 1—The total reinforcement area of the inner cage plus the middle cage shall not be less than that specified for the inner cage in Table 2.
NOTE 2—The total reinforcement area of the outer cage plus the middle cage shall not be less than that specified for the outer cage in Table 2.

FIG. 4 Vertical Elliptical Pipe

7.3.3 The manufacturer shall submit to the owner proof of the adequacy of the proposed modified and 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.

7.3.4 Such pipe shall meet all of the test and performance requirements specified by the owner in accordance with Section 5.

7.4 *Area*—In this specification, when the word area is not described by adjectives, such as cross-sectional 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 7 in. or three layers for pipe with wall thicknesses of 7 in. or greater. The layers shall not be separated by more than the thickness of one longitudinal plus ¼ in. 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 reinforcement is used, it shall be placed so that the cover of the concrete over the circumferential reinforcement at the vertical and horizontal diameters of the pipe is 1 in. from the inside and outside surfaces of the pipe, except for wall thicknesses less than 2½ in., the protective cover of the concrete over the circumferential reinforcement in the wall of the pipe shall be ¾ in.

8.1.2 Where two lines of reinforcement of elliptical shape corresponding to the contour of the pipe are used, each line shall be so placed that the covering of concrete over the reinforcement is 1 in.

8.1.3 The location of the reinforcement shall be subject to the permissible variations in dimensions given in 11.5. Requirements for placement and protective covering of the concrete from the inner or outer surface of the pipe do not apply to that portion of a cage which is flared so as to extend into the bell or reduced in diameter so as to extend into the spigot.

8.1.3.1 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 3 in. except that if this distance exceed one-half the wall thickness, the pipe wall shall contain at least a total reinforcement area of the minimum specified area per linear foot times the laying length of the pipe section. The minimum cover on the last circumferential near the spigot shoulder shall be ½ in.

8.1.3.2 Where the reinforcement is in the bell or spigot the minimum end cover on the last circumferential shall be ½ in. in the bell or ¼ in. in the spigot.

8.1.4 The spacing center to center of circumferential reinforcement in a cage shall not exceed 4 in. for pipe up to and including pipe having a 4-in. wall thickness nor exceed the wall thickness for larger pipe, and shall in no case exceed 6 in.

8.1.5 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.

8.1.6 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.

8.1.6.1 When splices are welded and are not lapped to the minimum requirements above, pull tests of representative specimens shall develop at least 90 % of the specified design yield strength of the circumferential wire, and there shall be a minimum lap of 2 in. with sufficient weld length to develop the required strength. For butt welded splices in bars or wire, permitted only in helically wound cages, pull tests of representative specimens shall develop at least 110 % of the specified design yield strength of the circumferential wire.