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## Standard Specification for Precast Reinforced Concrete Manhole Sections<sup>1</sup>

This standard is issued under the fixed designation C 478; 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.*

### PART I—GENERAL

#### 1. Scope

1.1 This specification covers the manufacture and purchase requirements of products used for the assembly and construction of circular vertical precast reinforced concrete manholes and structures used in sewer and water works.

1.2 Part I, Sections 1-11, of this specification presents general requirements and requirements that are common to each precast concrete product covered by this specification.

1.3 Part II of this specification presents specific requirements for each manhole product in the following sections:

Product	Section
Grade Rings	12
Flat Slab Tops	13
Risers and Conical Tops	14
Base Sections	15
Steps and Ladders	16

NOTE 1—Future products will to be included in Part II in a future revision of this specification.

1.4 A complete metric companion to this specification has been developed, Specification C 478M; therefore, no metric equivalents are presented in this specification.

NOTE 2—This specification is a manufacturing and purchase specification only and does not include requirements for backfill, or the relationship between field load conditions and the strength requirements of the manhole products and appurtenances. Experience has shown, however, that the successful performance of this product depends upon the proper selection of the product strength, type of foundation and backfill, and care in the field installation of the manhole products and connecting pipes. The owner of the project for which these products are specified herein is cautioned to require inspection at the construction site.

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<sup>1</sup> This specification is under the jurisdiction of ASTM Committee C13 on Concrete Pipe and is the direct responsibility of Subcommittee C13.06 on Manholes and Specials. Current edition approved March 4, 2007; 15, 2008. Published March 2007-2008. Originally approved in 1961. Last previous edition approved in 2006 as ~~C 478 – 06~~ C 478 – 07.

## 2. Referenced Documents

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

- A 82/A 82M Specification for Steel Wire, Plain, for Concrete Reinforcement
- A 185/A 185M Specification for Steel Welded Wire Reinforcement, Plain, for Concrete
- A 496/A 496M Specification for Steel Wire, Deformed, for Concrete Reinforcement
- A 497/A 497M Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete
- A 615/A 615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
- A 706/A 706M Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
- C 33 Specification for Concrete Aggregates
- C 39/C 39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
- C 150 Specification for Portland Cement
- C 260 Specification for Air-Entraining Admixtures for Concrete
- C 309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete
- C 494/C 494M Specification for Chemical Admixtures for Concrete
- C 497 Test Methods for Concrete Pipe, Manhole Sections, or Tile
- C 595 Specification for Blended Hydraulic Cements
- C 618 Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
- C 822 Terminology Relating to Concrete Pipe and Related Products
- C 989 Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
- C 1017/C 1017M Specification for Chemical Admixtures for Use in Producing Flowing Concrete

### 2.2 *ACI Standard:*<sup>3</sup>

- 318 Building Code, Requirements for Reinforced Concrete

## 3. Terminology

- 3.1 *Definitions*— For definitions of terms relating to precast reinforced concrete manholes, see Terminology C 822.

## 4. Materials and Manufacture

4.1 General material requirements for precast reinforced concrete manhole products are presented in 4.1.1-4.1.8. Other materials or additional requirements for a product, if any, are covered in the Part II section for that specific product.

4.1.1 *Reinforced Concrete*—Reinforced concrete shall consist of cementitious materials, mineral aggregates, and water, in which steel reinforcement has been embedded in such a manner so that the steel reinforcement and concrete act together.

### 4.1.2 *Cementitious Materials:*

4.1.2.1 *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 Specification C 595, except that the pozzolan constituent of the Type IP portland-pozzolan cement shall be fly ash.

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

4.1.2.3 *Ground Granulated Blast-Furnace Slag (GGBFS)* —GGBFS shall conform to the requirements of Grade 100 or 120 of Specification C 989.

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

- 4.1.3.1 Portland cement only,
- 4.1.3.2 Portland blast-furnace slag cement only,
- 4.1.3.3 Slag modified Portland cement only,
- 4.1.3.4 Portland pozzolan cement only,
- 4.1.3.5 A combination of Portland cement and ground granulated blast-furnace slag,
- 4.1.3.6 A combination of Portland cement and fly ash, or
- 4.1.3.7 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).

4.1.4 *Aggregates*—Aggregates shall conform to Specification C 33, except that the requirements for gradation shall not apply.

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

- 4.1.5.1 Air-entraining admixture conforming to Specification C 260;
- 4.1.5.2 Chemical admixture conforming to Specification C 494/C 494M;
- 4.1.5.3 Chemical admixture for use in producing flowing concrete conforming to Specification C 1017/C 1017M;
- 4.1.5.4 Chemical admixture or blend approved by the owner.

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

<sup>3</sup> Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, <http://www.aci-int.org>.

4.1.6 *Steel Reinforcement*—Reinforcement shall consist of wire conforming to Specification A 82/A 82M or Specification A 496/A 496M, of wire fabric conforming to Specification A 185/A 185M or Specification A 497/A 497M, or of bars of Grade 40 steel conforming to Specification A 615/A 615M or of bars conforming to Specification A 706/A 706M.

4.1.7 *Secondary Synthetic Fiber*—Collated fibrillated polypropylene virgin fibers shall not be prohibited when used in steel reinforced concrete manholes as a non-structural manufacturing enhancement. Only fibers designed and manufactured specifically for use in concrete and so certified by the manufacturer shall be accepted.

4.1.8 *Other Materials*—Other materials required for a product and not covered in Section 4 will be covered in the Part II section for that specific product.

## 5. Design

5.1 Design requirements for a product are prescribed in the specific Part II section for that product.

5.1.1 The minimum compressive strength of concrete manhole products covered by this specification shall be 4000 psi unless specified otherwise in Part II of this specification.

### 5.2 *Modified or Special Design*

5.2.1 Manufacturers are not prohibited from submitting to the owner, for approval prior to manufacture, designs other than those prescribed in the specific section for a product. If such approval is obtained, then the product shall meet all the tests and performance requirements specified by the owner in accordance with the appropriate sections on manufacture and physical requirements.

5.2.2 If permitted by the owner, the manufacturer is not prohibited from requesting approval of designs of special sections, such as reducers, tees, and bases.

## 6. Reinforcement

6.1 This section presents requirements for reinforcement cover, continuity, laps, welds, and splices. Other reinforcement requirements are presented in Section 4, and any additional requirements are given in the Part II section for a specific product.

6.2 *Cover*—The exposure of the ends of reinforcement, stirrups or spacers used to position the reinforcement during placement of the concrete shall not be cause for rejection.

6.3 *Continuity*—The continuity of the circumferential reinforcement shall not be destroyed during the manufacture of the product, except when lift holes or pipe openings are provided in the product.

### 6.4 *Welded Steel Cage Laps, Welds, and Splices:*

6.4.1 If splices are not welded, the reinforcement shall be lapped not less than 20 diameters for deformed bars, 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.

6.4.2 When splices are welded and are not lapped to the minimum requirements in 6.4.1, 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 2 in. 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.

6.5 *Steel Hoop Splices*—A representative sample steel hoop with welded splices shall develop at least 50 % of the minimum specified strength of the steel, and there shall be a minimum lap of 2 in. For butt welded splices, the representative steel hoop sample shall develop at least 75 % of the minimum specified strength of the steel.

## 7. Precast Concrete Manufacture

7.1 *Mixture*—The aggregates shall be sized, graded, proportioned, and mixed with such proportions of cementitious materials and water as will produce a homogeneous concrete mixture of such quality that the products will conform to the test and design requirements of this specification. All concrete shall have a water-cementitious ratio not exceeding 0.53 by weight. Cementitious materials shall be as specified in 4.1.2 and shall be added to the mix in a proportion not less than 470 lb/yd<sup>3</sup>, unless mix designs with a lower cementitious materials content demonstrate that the quality and performance of the product meet the requirements of this specification.

7.2 *Curing*—Concrete products shall be subjected to any one of the methods of curing prescribed in 7.2.1-7.2.4 or to any other method or combination of methods approved by the owner that will give satisfactory results.

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

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

7.2.3 *Sealing Membrane*—A sealing membrane conforming to the requirements of Specification C 309 is applied and shall be left intact until the required concrete strength requirements are met. The concrete at the time of application of the membrane shall be within 10°F of the atmospheric temperature. All concrete surfaces shall be kept moist prior to the application of the membrane and shall be damp when the membrane is applied.

7.2.4 The manufacturer is not prohibited from combining the methods prescribed in 7.2.1-7.2.3 provided the required concrete compressive strength is attained.

## 8. Acceptance

### 8.1 *Acceptance Procedures:*

8.1.1 Unless otherwise designated by the owner at the time of, or before, placing an order, acceptance procedures for precast reinforced concrete manhole products shall be as specified in the Part II section for a particular product, and shall not be prohibited from consisting of one or more of the following:

8.1.1.1 Acceptance of a product on the basis of tests of materials, including concrete compressive strength and absorption.

8.1.1.2 Acceptance of a product on the basis of inspection of the finished product, including amount and placement of reinforcement to determine conformance with the design prescribed under this specification, and freedom from defects.

### 8.2 *Test Methods:*

#### 8.2.1 *Concrete Compressive Strength Test:*

8.2.1.1 *Type of Specimen*—Compression tests for satisfying the minimum specified concrete strength requirement shall be made on either concrete cylinders or, at the option of the manufacturer, on cores cut from the concrete manhole product.

8.2.1.2 *Compression Testing of Cylinders*—Cylinders shall be made in accordance with Test Methods C 497, and shall be tested in accordance with Test Method C 39. For manhole products, an owner shall not be prohibited from requiring concrete compressive tests on cylinder specimens numbering in the amount of 5 % of the total order of a manhole product, but not to exceed two cylinders for each day's production. The average compressive strength of all cylinders tested shall be equal to or greater than the specified strength of the concrete. Not more than 10 % of the cylinders tested shall fall below the specified strength of the concrete. In no case shall any cylinder tested fall below 80 % of the specified strength of the concrete.

8.2.1.3 *Compression Testing of Cores*—Cores shall be cut from the concrete manhole product and tested in accordance with Test Methods C 497, except that the requirements for moisture conditioning shall not apply. One core shall be taken from a manhole product selected at random from each day's production run of a single concrete strength. When the concrete compressive strength of the core is equal to or greater than 80 % of the specified strength of the concrete, the concrete strength of the production run is acceptable. If the core does not meet the preceding concrete strength requirement, another core from the same manhole product shall be taken and tested.

8.2.1.4 If the concrete compressive strength of the recore is equal to or greater than 80 % of the specified strength of the concrete, the concrete strength of the production run is acceptable. If the recore does not meet the preceding concrete strength requirement, that manhole product shall be rejected. Two manhole products from the remainder of the day's production run shall be selected at random and one core taken from each manhole product and tested. When the average concrete strength of the two cores is equal to or greater than 80 % of the specified strength of the concrete with no core below 75 % of the specified strength of the concrete, the concrete strength of the day's production run shall be acceptable.

8.2.1.5 If the concrete strength of the two cores does not meet the preceding concrete strength requirement, then the remainder of the day's production run shall be either rejected, or, at the option of the manufacturer, each manhole product of the remainder of the day's production run is not prohibited from being cored and accepted individually.

8.2.1.6 *Plugging Core Holes*—Core holes on accepted concrete manhole products shall be plugged and sealed by the manufacturer in a manner such that the manhole products will meet all of the requirements of this specification. Manhole sections so sealed shall be considered as satisfactory for use.

#### 8.2.2 *Absorption Test:*

8.2.2.1 The absorption of a specimen from a concrete product, as determined in Test Methods C 497, shall not exceed 9 % of the dry mass for Test Method A procedure or 8.5 % for Test Method B procedure. All specimens shall be free of visible cracks and shall represent the full thickness of the product.

8.2.2.2 Specimens for Test Method B shall meet the requirements of Test Methods C 497.

8.2.2.3 Each specimen tested by Test Method A shall have a minimum weight of 2.2 lbs.

8.2.2.4 When the initial absorption specimen from a concrete product fails to conform to this specification, the absorption test shall be made on another specimen from the same product and the results of the retest shall be substituted for the original test results.

8.2.3 *Retests*—When not more than 20 % of the concrete test specimens tested under either 8.2.2.1 or 8.2.2.2 fail to pass the requirements of this specification, the manufacturer is not prohibited from culling his stock and eliminating whatever quantity of product he desires and shall so mark the culled product that they will not be shipped for the order. The required tests shall be made on the balance of the order and the products shall be accepted if in conformance with the requirements of this specification.

8.3 *Test Equipment*—Every manufacturer furnishing manhole products under this specification shall furnish all facilities and personnel necessary to carry out the tests required for acceptance.

## 9. Repairs

9.1 Repair of manhole products shall not be prohibited, if necessary, because of imperfections in manufacture or damage during handling, and will be acceptable if, in the opinion of the owner, the repaired products conform to the requirements of this specification.

## 10. Inspection

10.1 The quality of materials, the process of manufacture, and the finished manhole products shall be subject to inspection and approval by the owner.

## 11. Product Marking

11.1 The following information shall be legibly marked on each precast concrete product:

11.1.1 Specification and product designation: MH for manhole base, riser, conical tops, and grade rings,

11.1.2 Date of manufacture, and

11.1.3 Name or trademark of the manufacturer.

11.2 Marking shall be indented into the concrete or shall be painted thereon with waterproof paint.

## PART II—PRODUCTS

### 12. Grade Rings

12.1 *Scope*—This section covers precast reinforced concrete grade rings used for final adjustment of manholes to grade.

12.2 *Acceptance*—Acceptability of grade rings covered by this specification shall be determined by the results of such tests of materials as are required by Section 4; by compressive strength tests on concrete cores or concrete cylinders required by Section 8; and by inspection of the finished product, including amount and placement of reinforcement as prescribed by 12.4, 12.5, and 12.6, to determine its conformance with the design prescribed under this specification and its freedom from defects.

12.3 *Design*—The minimum wall thickness shall be one twelfth of the internal diameter of the grade ring or 4 in., whichever is greater.

12.3.1 *Joints*—Grade rings are not required to have the joint formed with male and female ends.

12.4 *Circumferential Reinforcement* :

12.4.1 The circumferential reinforcement shall have an equivalent area of not less than 0.07 in.<sup>2</sup>/vertical ft, but not less than 0.024 in.<sup>2</sup> in any one grade ring.

12.4.2 The circumferential reinforcement shall be one line in the center third of the wall of the grade ring.

12.5 *Permissible Variations*:

12.5.1 *Internal Diameter*—The internal diameter of grade rings shall not vary more than  $\pm 1\%$ .

12.5.2 *Wall Thickness*—The wall thickness of grade rings shall be not less than that prescribed in the design by more than 5% or  $\pm \frac{3}{16}$  in., whichever is greater. A wall thickness greater than that prescribed in the design shall not be cause for rejection.

12.5.3 *Height of Two Opposite Sides* —Variations in laying height of two opposite sides of grade rings shall be not more than  $\frac{1}{4}$  in.

12.5.4 *Height of Grade Ring*—The underrun in height of a grade ring shall be not more than  $\frac{1}{8}$  in./ft of height.

12.5.5 *Position of Reinforcement*—For grade rings with a 4-in. wall thickness, the maximum variation in the design position of circumferential reinforcement from that described in 12.4.1 shall be  $\pm 10\%$  of the wall thickness or  $\pm \frac{1}{4}$  in., whichever is greater. For grade rings with a wall thickness greater than 4 in., the maximum variation from the design position of reinforcement shall be  $\pm 10\%$  of the wall thickness or  $\pm \frac{5}{8}$  in., whichever is the lesser. In no case, however, shall the cover over the reinforcement be less than  $\frac{3}{4}$  in. The preceding minimum cover limitation does not apply to the mating surfaces of the joint.

12.5.6 *Area of Reinforcement*—Steel reinforcement areas that are 0.005 in.<sup>2</sup>/linear ft less than called for by design shall be considered as meeting the required steel reinforcement area.

12.6 *Rejection*:

12.6.1 Grade rings shall be subject to rejection for failure to conform to any of the specification requirements. In addition, an individual grade ring shall be subject to rejection because of any of the following:

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

12.6.1.2 Defects that indicate mixing and molding not in compliance with 7.1 or surface defects indicating honeycombed or open texture that would adversely affect the function of the grade ring.

12.6.1.3 The planes of the ends are not perpendicular to the longitudinal axis of the grade ring, within the limits of permissible variations prescribed in 12.5.

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

12.6.1.5 Any continuous crack having a surface width of 0.01 in. or more and extending for a length of 12 in. or more, regardless of position in the wall.

### 13. Flat Slab Tops

13.1 *Scope*—This section covers precast reinforced concrete flat slab tops used in the construction of manholes for use in sewer and water works.

13.2 *Acceptance*:

13.2.1 Acceptability of flat slab tops shall be determined by the results of such tests of materials as are required by Section 4; by compressive strength tests on concrete cores or concrete cylinders required by Section 8; and by inspection of the finished product, including amount and placement of reinforcement as prescribed by 13.4 and 13.6, to determine its conformance with the design prescribed under this specification and its freedom from defects.

13.2.2 Unless otherwise designated by the owner at the time of, or before, placing an order, two separate and alternative methods of acceptance are permitted for flat slab top manufacturer designs, in addition to tests of materials and inspection required in 13.2.1.

13.2.2.1 *Acceptance on the Basis of Proof-of-Design Test*—Acceptance of flat slab tops on the basis of the results of a proof-of-design test performed in accordance with 13.5 in lieu of submission of design calculations and detailed drawings.

13.2.2.2 *Acceptance on the Basis of Rational Design*—Acceptance of flat slab tops on the basis of design calculations by a rational method and detailed drawings.

### 13.3 *Design:*

13.3.1 The basis of flat slab top designs shall be the appropriate sections of the latest edition of ACI 318.

13.3.2 Flat slab tops shall have a minimum thickness of 6 in. for risers up to and including 48 in. in diameter and 8 in. for larger diameters.

13.3.3 The flat slab top access opening shall be a minimum of 24 in. in diameter.

13.3.4 *Joint*—The reinforced concrete flat slab top shall be formed with or without a male or female end so that when the manhole base, riser and top section are assembled, they will make a continuous and uniform manhole compatible with the tolerances given in 13.6.

13.3.4.1 Joints are designed to perform in axial compression; therefore, shear or load testing of the joint is not required.

### 13.4 *Reinforcement:*

13.4.1 Flat slab tops manufactured with a joint or with other indication of the top or bottom of the slab shall be manufactured with one layer of reinforcement placed near the bottom surface so that the protective cover over the reinforcement shall be 1 in.

13.4.2 Flat slab tops manufactured without a joint or without other indication of the top or bottom of the slab shall be manufactured with two layers of steel reinforcement, one located near the bottom surface and one near the top surface so that the protective cover over each layer is 1 in.

13.4.3 A layer of reinforcement shall have a minimum area of 0.12 in.<sup>2</sup>/linear ft in both directions.

13.4.4 Openings in flat slab tops shall be additionally reinforced with a minimum of the equivalent of 0.20 in.<sup>2</sup> of steel at 90°. Straight rods used to reinforce openings shall have a minimum length equal to the diameter of the opening plus 2 in.

13.5 *Physical Requirements*—Physical requirements for tests shall conform to the requirements of Section 8.

### 13.5.1 *Proof-of-Design Test:*

13.5.1.1 If 13.2.2.2 has been designated as the basis of acceptance, one flat slab top for each design shall be tested unless the owner has indicated otherwise.

13.5.1.2 The flat slab top proof-of-design test procedures shall be in accordance with Test Methods C 497.

13.5.1.3 The ultimate test load shall be the sum of at least 130 % of the dead load on the slab plus at least 217 % of the live-plus impact load on the slab. Dead load is the weight of the column of earth over the slab plus the weight of the riser supported by the slab. Live load is the maximum anticipated wheel load that may be transmitted through the riser to the slab.

13.5.1.4 The flat slab top shall be acceptable if it supports the required ultimate test load without failure. Ultimate strength failure is defined as the inability of the slab to resist an increase in the applied load.

13.5.1.5 When agreed upon by the owner and manufacturer, the flat slab top shall be acceptable based on certified copies of the results of tests performed on identical flat slab tops instead of requiring new proof-of-design acceptance tests.

### 13.6 *Permissible Variations:*

13.6.1 *Internal Diameter*—The internal diameter of the flat slab tops entrance hole shall not vary more than  $\pm 1$  %.

13.6.2 *Thickness*—The thickness of flat slab tops shall be not less than that prescribed in the design by more than 5 % or  $\pm 3/16$  in., whichever is greater. A thickness greater than that prescribed in the design shall not be cause for rejection.

13.6.3 *Length of Two Opposite Sides* —Variations in lengths of two opposite sides of flat slab tops shall be not more than  $1/4$  in.

13.6.4 *Length*—The underrun in length of a flat slab top shall be not more than  $1/8$  in./ft of length.

13.6.5 *Position of Reinforcement*—For flat slab tops with less than a 6 in. thickness, the maximum variation in the position of reinforcement from that prescribed in 13.5 shall be  $\pm 10$  % of the thickness or  $\pm 1/4$  in., whichever is greater. For flat slab tops with a thickness greater than 6 in., the maximum variation shall be  $\pm 10$  % of the thickness or  $\pm 5/8$  in., whichever is the lesser. In no case, however, shall the cover over the reinforcement be less than  $3/4$  in.

13.6.6 *Area of Reinforcement*—Steel reinforcement areas that are 0.005 in.<sup>2</sup>/linear ft less than called for by design shall be considered as meeting the required steel reinforcement area.

### 13.7 *Rejection:*

13.7.1 Flat slab tops shall be subject to rejection for failure to conform to any of the specification requirements. In addition, an individual flat slab top of shall be subject to rejection because of any of the following:

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

13.7.1.2 Defects that indicate mixing and molding not in compliance with 7.1 or surface defects indicating honeycombed or open texture that would adversely affect the function of the flat slab top.

13.7.1.3 The planes of the ends are not perpendicular to the longitudinal axis of the flat slab top, within the limits of permissible variations prescribed in 13.6.