

Standard Specifications for Tolerances for Concrete Construction and Materials (ACI 117-90)

Reported by ACI Committee 117

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This specification provides standard tolerances for concrete construction. This document is intended to be used as the reference document for establishing tolerances for concrete construction by specification writers and ACI committees writing Standards.

Keywords: bending (reinforcing steels); building codes; **concrete construction**; concrete piles; concretes; floors; formwork (construction); masonry; mass concrete; piers; precast concrete; prestressed concrete; reinforcing steels; **specifications**; splicing; **standards**; **tolerances (mechanics)**.

FOREWORD

F1. This foreword is included for explanatory purposes only; it is not a part of Standard Specification 117.

F2. Standard Specification 117 is a Reference Standard which the Architect/Engineer may cite in the Project Specifications for any construction project, together with supplementary requirements for the specific project.

This standard is not intended to apply to special structures not cited in the standard such as nuclear reactors and containment vessels, bins and silos, and prestressed circular structures. It is also not intended to apply to the specialized construction procedure of shotcrete.

F3. Standard Specification 117 *addresses each of the Three-Part Section Format* of the Construction Specifications Institute, *organized by structural elements, structural components and types of structures*; the numbering system *reflects this organization*. The language is imperative and terse to preclude an alternative.

F4. A Specification Checklist is included as a preface to, but not forming a part of, Standard Specification 117. The purpose of this Specification Checklist is to assist the Architect/Engineer in properly choosing and specifying the necessary mandatory and optional requirements for the Project Specification.

PREFACE TO SPECIFICATION CHECKLIST

P1. Standard Specification 117 is intended to be used in its entirety by reference in the Project Specification. Individual sections, articles, or paragraphs should not be copied into the Project Specifications since taking them out of context may change their meaning.

P2. Building codes establish minimum requirements necessary to protect the public. Some of the requirements in this Standard Specification may be more stringent than the minimum in order to insure the level of quality and performance that the Owner expects the structure to provide. Adjustments to the needs of a particular project should be made by the Architect/Engineer by reviewing each of the items in the Specification Checklist and then including the Architect/Engineer's decision on each item as a mandatory requirement in the Project Specifications.

P3. These mandatory requirements should designate the specific qualities, procedures, materials, and performance criteria for which alternatives are permitted or for which provisions were not made in the Standard Specification. Exceptions to the Standard Specification should be made in the Project Specifications, if required.

P4. A statement such as the following will serve to make Standard Specification ACI 117 an official part of the Project Specifications:

Tolerances for Concrete Construction and Materials shall conform to all requirements of ACI 117, Standard Specifications for Tolerances for Concrete Construction and Materials, published by the American Concrete Institute, Detroit, Michigan, except as modified by the requirements of these Contract Documents.

Adopted as a Standard of the American Concrete Institute in November 1989 in accordance with the Institute's standardization procedures.

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*Chairman during initial development of this document.

P5. The Specification Checklist that follows is addressed to each item of the Standard Specification where the Architect/Engineer must or may make a choice of alternatives; may add provisions if not indicated; or may take exceptions. The Specification

Checklist consists of two columns; the first identifies the sections, parts, and articles of the Standard Specification and the second column contains notes to the Architect/Engineer to indicate the type of action required by the Architect/Engineer.

MANDATORY SPECIFICATION CHECKLIST

| Section/Part/Article | Notes to the Architect/Engineer |
|---|---|
| Section 2 - Materials 2.2-Reinforcement | Tolerances for fabrication, placement, and lap splices for welded wire fabric must be specified by the specifier. |
| Section 3 - Foundations 3.1.1 Drilled piers | Specify category of caisson. The designer should be aware that the recommended vertical alignment tolerance of 1.5 percent of the shaft length indicated in Category B caissons is based on experience in a wide variety of soil situations combined with a limited amount of theoretical analysis using the beam on elastic foundation theory and minimum assumed horizontal soil restraint. |
| Section 4 - Cast-in-place concrete for buildings 4.5.4 Form offsets 4.5.5 Floor finish 4.5.5.1 For Section 4.5.6 4.5.5.2 For Section 4.5.7 | Designate class of surface (A, B, C, D): Class A - For surfaces prominently exposed to public view where appearance is of special importance. Class B - Coarse-textured concrete-formed surfaces intended to receive plaster, stucco, or wainscoting. Class C - General standard for permanently exposed surfaces where other finishes are not specified. Class D - Minimum quality surface where roughness is not objectionable, usually applied where surfaces will be concealed. Specify floor finish tolerance measurement method (either Section 4.5.6 or Section 4.5.7). Designate floor classification (15/13; 20/15; 30/20; or, 50/30). Designate maximum gap under a freestanding straightedge (1/2 in., 5/16 in., 3/16 in., or 1/8 in.). |

OPTIONAL SPECIFICATION CHECKLIST

| | |
|---|--|
| Section 1 - General 1.1.2 Scope | Tolerance values affect construction cost. Specific use of a tolerated item may warrant less or more stringent tolerances than contained in the specification. Such variances must be individually designated by the specifier in the contract documents. |
| 1.1.2 Scope | Tolerances in this specification are for standard concrete construction and construction procedures. Specialized concrete construction or construction procedures require specifier to include specialized tolerances. AC1 committee documents covering specialized construction may provide guidance on specialized tolerances. The tolerances in this Specification do not apply to special structures or procedures not cited in the document such as nuclear reactors and containment vessels, bins and silos, circular prestressed concrete tank structures and shotcrete. |
| 1.2.3 Requirements | Where a specific application uses multiply tolerated items that together yield a tolerated result, the specifier must analyze the tolerance envelope with respect to practical limits and design assumptions and specify its value where the standard tolerances values in this specification are inadequate or inappropriate. |

OPTIONAL SPECIFICATION CHECKLIST, continued

| | |
|---|--|
| Section 2 - Materials 2.2.3 Concrete cover | The tolerance for reduction in cover in reinforcing steel may require a reduction in magnitude where the reinforced concrete is exposed to chlorides or the environment. Where possible excess cover or other protection of the reinforcing steel should be specified in lieu of reduced tolerance because of the accuracy of locating reinforcing steel utilizing standard fabrication accessories and installed procedures. Tolerance given is for general application. Specific design use of embedded items may require the specifier to designate tolerances of reduced magnitude for various embedded items. |
| 2.3.2 Embedded items | |
| Section 3 - Cast-in-place concrete for foundations 3.4.1.2 Footings | Plus tolerance for the vertical dimensions is not specified because no limit is imposed. Specifier must designate plus tolerance if desired. |
| Section 4 - Cast-in-place concrete for buildings 4.5.5 Floor finish | The procedures for specifying and measuring floor finish tolerances set forth herein are not appropriate for narrow aisle warehouse floors with defined traffic lanes designed for use by specialized wheeled equipment. Consult specific equipment manufacturers for their recommendations. |
| Section 5 - Precast concrete | The tolerances for precast concrete are intended to apply to all types of precast concrete construction cast onsite (<i>including tilt-up</i>) and offsite except as set forth below. Variations to these tolerances may be advisable after consideration of panel size and construction techniques required. |
| 5.1.4 Camber | Tolerances set forth herein are not intended to apply to plant production of patented or copyrighted structural systems and/or elements. Designers, specifiers and contractors should contact the Licensors of such systems and/or products for applicable tolerances. For members with a span-to-depth ratio equal to or exceeding 30, the stated camber tolerance may require special production measures and result in cost premiums. Where feasible, a greater tolerance magnitude should be utilized where the span-to-depth ratio is equal to or greater than 30. |
| 5.3 Planer elements | Industrial precast products may not conform to the planar tolerances. Manufacturers should be consulted for appropriate tolerances for their products. |

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SECTION 1 - GENERAL REQUIREMENTS

1.1 - Scope

1.1.1 This specification designates standard tolerances for concrete construction.

1.1.2 The indicated tolerances govern unless otherwise specified.

1.2 - Requirements

1.2.1 Concrete construction shall meet the specified tolerances.

1.2.2 Tolerances shall not extend the structure beyond legal boundaries.

1.2.3 Tolerances are not cumulative. The most restrictive tolerance controls.

1.2.4 Plus (+) tolerance increases the amount or dimension to which it applies, or raises a level alignment. Minus (-) tolerance decreases the amount or dimension to which it applies, or lowers a level alignment. A nonsigned tolerance means + or -. Where only one signed tolerance is specified (+ or -), there is no limit in the other direction.

1.3 - Definitions

Arris - The line, edge, or hip in which two straight or curved surfaces of a body, forming an exterior angle, meet; a sharp ridge, as between adjoining channels of a Doric column.

Bowing - The displacement of the surface of a planar element from a plane passing through any three corners of the element.

Clear distance - In reinforced concrete, the least distance between the surface of the reinforcement and the referenced surface, i.e., the form, adjacent reinforcement, embedment, concrete, or other surface.

Concealed surface - Surface not subject to visual observation during normal use of the element.

Contract documents - The project contract, the project drawings, and the project specifications.

Cover - In reinforced concrete, the least distance between the surface of the reinforcement and the outer surface of the concrete.

Flatness - The degree to which a surface approximates a plane.

Lateral alignment - The location relative to a specified horizontal line or point in a horizontal plane.

Level alignment - The location relative to a specified horizontal plane. When applied to roadways, bridge decks, slabs, ramps, or other nominally horizontal surfaces established by elevations, level alignment is defined as the vertical location of the surface relative to the specified profile grade and specified cross slope.

Levelness - The degree to which a line or surface parallels horizontal.

Precast linear element - Beam, column, or similar unit.

Precast planar element - Wall panel, floor panel, or similar unit.

Project Specifications - The building specifications which employ ACI 117 by reference, and which serve as the instrument for making the mandatory and optional selections available under these and for specifying items not covered herein.

Relative alignment - The distance between two or more elements in any plane, or the distance between adjacent elements, or the distance between an element and a defined point or plane.

Spiral - As used in circular stave silo construction, is defined as the distortion that results when the staves are misaligned so that their edges are inclined while their outer faces are vertical. The resulting assembly

appears twisted with the vertical joints becoming long-pitch spirals.

Specified surface, plane, or line - A surface, plane, or line specified by the contract documents; specified planes and lines may slope and specified surfaces may have curvature.

Tolerance -

1. The permitted variation from a given dimension or quantity.

2. The range of variation permitted in maintaining a specified dimension.

3. A permitted variation from location or alignment.

Vertical alignment - The location relative to specified vertical plane or a specified vertical line or from a line or plane reference to a vertical line or plane. When applied to battered walls, abutments or other nearly vertical surfaces, vertical alignment is defined as the

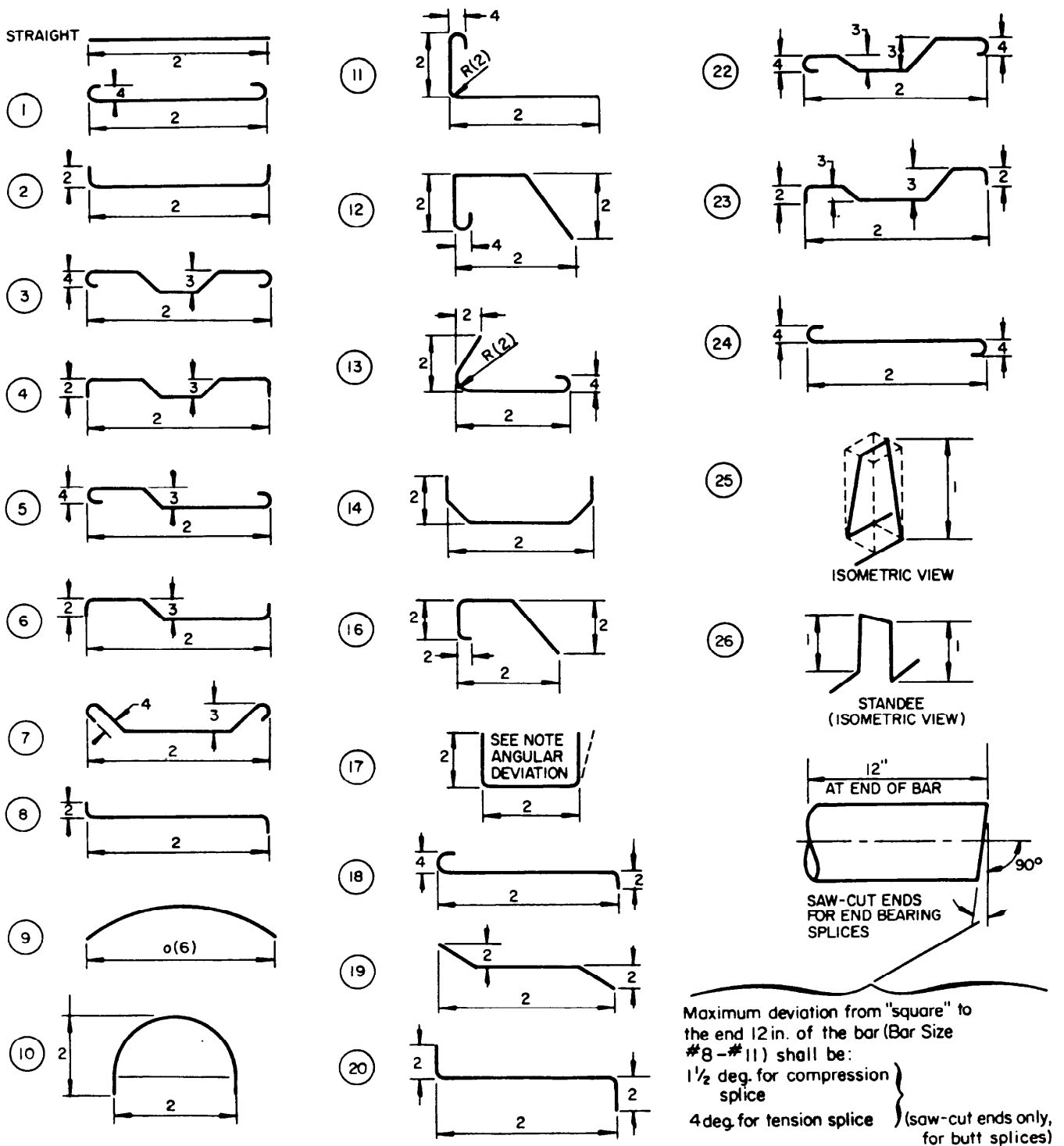
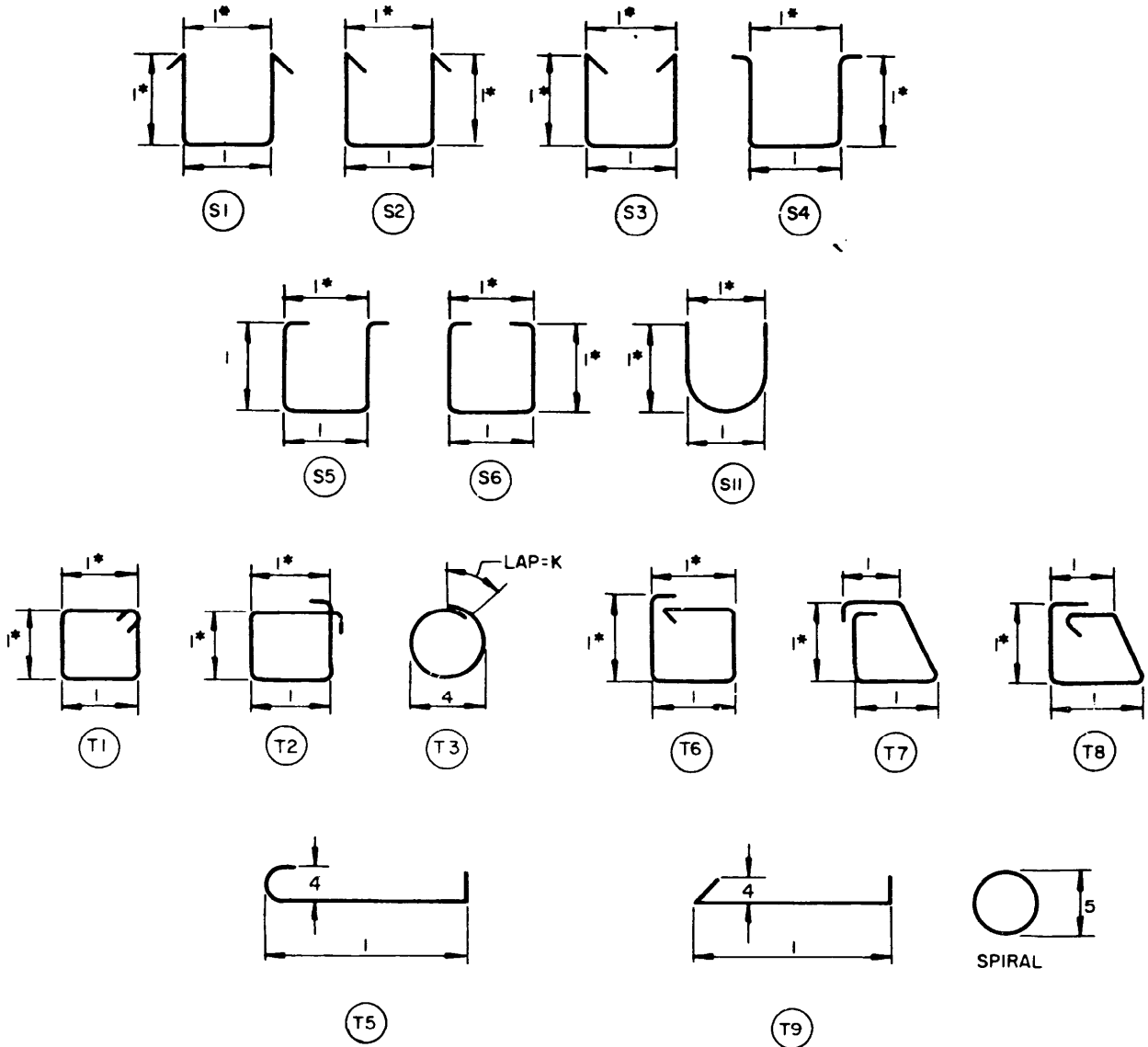


Fig. 2.1(a) - Standard fabricating tolerances for bar sizes #3 through #11



NOTES:

Entire shearing and bending tolerances are customarily absorbed in the extension past the last bend in a bent bar.

All tolerances single plane and as shown. Tolerances for Types S1 through S6, S11, and T1 through T9 apply only the Bar Sizes #3 through #8.

*Dimensions on this line are to be within tolerance shown, but are not to differ from opposite parallel dimension more than 1/2 in.

Angular deviation-Maximum plus or minus 2-1/2 deg or plus or minus 1/2 in. per ft, but not less than 1/2 in., on all 90-deg hooks and bends.

TOLERANCE SYMBOLS:

1. Bar Sizes #3, #4, #5:
= plus or minus 1/2 in. when gross bar length < 12 ft
= plus or minus 1 in. when gross bar length ≥ 12 ft
2. Plus or minus 1 in.
3. Plus 0, minus 1/2 in.
4. Plus or minus 1/2 in.
5. Plus or minus 1/2 in. for diameter ≤ 30 in.
Plus or minus 1 in. for diameter > 30 in.
6. Plus or minus 1.5 percent of *o* dimension ≥ plus or minus 2 in. minimum. If application of positive tolerance to Type 9 results in a chord length equal to or greater than the arc or bar length, the bar may be shipped straight.

Fig. 2.1(a) - Standard fabricating tolerances for bar sizes #3 through #11

horizontal location of the surface relative to the specified profile.

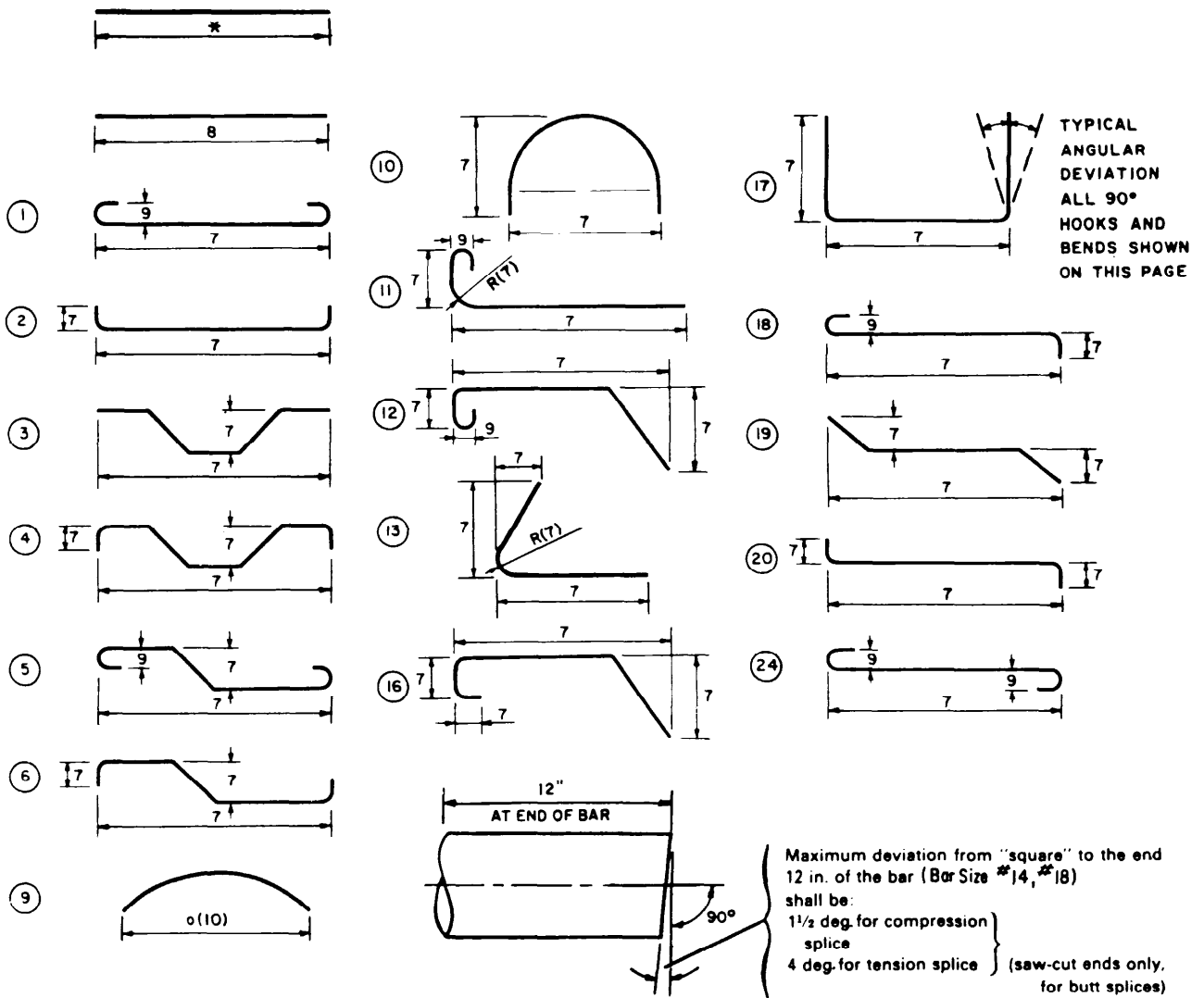
Warping - The displacement of the surface, portion, or edge of a planar element from a plane passing through any three corners of the element.

SECTION 2 - MATERIALS

2.1 - Reinforcing steel fabrication

For bars #3 and #11 in size, see Fig. 2.1(a).

For bars #14 and #18 in size, see Fig. 2.1(b).



NOTES:

Entire shearing and bending tolerances are customarily absorbed in the extension past the last bend in a bent bar.
 All tolerances single plane and as shown.
 Angular deviation - Maximum plus or minus 2-1/2 deg or plus or minus 1/2 in. per ft on all 90-deg hooks and bends.

TOLERANCE SYMBOLS:

| | | |
|---------------------------|------------------|------------------|
| | #14 | #18 |
| 7. Plus or minus | 2-1/2 in. | 3-1/2 in. |
| 8. Plus or minus | 2 in. | 2 in. |
| 9. Plus or minus | 1-1/2 in. | 2 in. |
| 10. Plus or minus | | |
| 2 percent x o dimension ≥ | ±2-1/2 in.† min. | ±3-1/2 in.† min. |

Fig. 2.1(b) - Standard fabricating tolerances for bar sizes #14 and #18

2.2 - Reinforcement placement

2.2.1 Tolerances shall not permit a reduction in cover except as set forth in Section 2.2.3 hereof.

2.2.2 Clear distance to side forms and resulting concrete surfaces and clear distance to formed and resulting concrete soffits in direction of tolerance

- When member size is 4 in. or less + 1/4 in.
 - 3/8 in.
- When member size is over 4 in. but not over 12 in. 3/8 in.
- When member size is over 12 in. but not over 2 ft 1/2 in.
- When member size is over 2 ft. 1 in.

2.2.3 Concrete cover measured perpendicular to concrete surface in direction of tolerance

- When member size is 12 in. or less - 3/8 in.
- When member size is over 12 in. - 1/2 in.

Reduction in cover shall not exceed one-third specified concrete cover.

Reduction in cover to formed soffits shall not exceed 1/4 in.

2.2.4 Distance between reinforcement:

- One-quarter specified distance not to exceed 1 in.
- Providing that distance between reinforcement shall not be less than the greater of the bar di-

iameter or 1 in. for unbundled bars.

For bundled bars, the distance between bundles shall not be less than the greater of 1 in. or 1.4 times the individual bar diameter for 2 bar bundles, 1.7 times the individual bar diameter for 3 bar bundles and 2 times the individual bar diameter for 4 bar bundles.

2.2.5 Spacing of nonprestressed reinforcement, deviation from specified location

In slabs and walls other than stirrups and ties
 Stirrups 3 in.
 Stirrups depth of beam in inches/12 x 1 in.
 Ties
 least width of column in inches/12 x 1 in.

However, total number of bars shall not be less than that specified.

2.2.6 Placement of prestressing reinforcement or prestressing steel ducts

2.2.6.1 Lateral placement

Member depth (or thickness) 24 in. or less
 1/2 in.
 Member depth (or thickness) over 24 in. 1 in.

2.2.6.2 Vertical placement

Member depth (or thickness) 8 in. or less
 1/4 in.
 Member depth (or thickness) over 8 in. but not over 24 in. 3/8 in.
 Member depth (or thickness) more than 24 in. 1/2 in.

2.2.7 Longitudinal location of bends and ends of bars:

At discontinuous ends of members 1 in.
 At other locations 2 in.

Table 2.4

| Material | Tolerance |
|--|--|
| Cementitious materials 30% of scale capacity or greater Less than 30% of scale capacity | 1% of cumulative weight - 0% to + 4% of the required cumulative weight |
| Water Added water or ice | 1% of the total water content which includes added water, ice, and water on aggregates |
| Total water content | 3% of total water content |
| Aggregates a) Cumulative batching Over 30% of scale capacity 30% of scale capacity or less b) Individual material batching | 1% of the required cumulative weight 0.3% of scale capacity or 3% of the required cumulative weight, whichever is less 2% of the required weight |
| Admixtures | 3% of the required amount |

2.2.8 Embedded length of bars and length of bar laps:

#3 through #11 bar sizes - 1 in.
 #14 and #18 bar sizes (embedment only) - 2 in.

2.2.9 Bearing plate for prestressing tendons, deviation from specified plane 1 degree

2.3 - Placement of embedded items

2.3.1 Clearance to reinforcement the greater of the bar diameter or 1 in.

2.3.2 Vertical alignment, lateral alignment, and level alignment 1 in.

2.4 - Concrete batching

See Table 2.4.

2.5 - Concrete properties

2.5.1 Slump, where specified as "maximum" or "not to exceed," for all values. + 0 in.

Specified slump 3 in. or less - 1-1/2 in.

Specified slump more than 3 in. - 2-1/2 in.

Slump, when specified as a single value

Specified slump 4 in. or less 1 in.

Specified slump more than 4 in. 1-1/2 in.

Where range is specified there is no tolerance.

2.5.2 Air content, where no range is specified and specified air content by volume is 4 percent or greater. 1-1/2 percent

Where range is specified, there is no tolerance.

SECTION 3 - FOUNDATIONS

3.1 - Vertical alignment

3.1.1 Drilled piers

3.1.1.1 Category A - For unreinforced shafts extending through materials offering no or minimal lateral restraint (i.e., water, normally consolidated organic soils, and soils that might liquefy during an earthquake) - 12.5 percent of shaft diameter.

3.1.1.2 Category B - For unreinforced shafts extending through materials offering lateral restraint (soils other than those indicated in Category A) - not more than 1.5 percent of the shaft length.

3.1.1.3 Category C - For reinforced concrete shafts - not more than 2.0 percent of the shaft length.

3.2 - Lateral alignment

3.2.1 Footings

As cast to the center of gravity as specified; 0.02 times width of footing in direction of misplacement but not more than 2 in.
 Supporting masonry 1/2 in.

3.2.2 Drilled piers

3.2.2.1 1/24 of shaft diameter but not more than 3 in.

3.3 - Level alignment

3.3.1 Footings

3.3.1.1 Top of footings supporting masonry 1/2 in.

3.3.1.2 Top of other footings + 1/2 in.
 - 2 in.

3.3.2 Drilled piers

3.3.2.1 Cut-off elevation + 1 in.
 - 3 in.

3.4 - Cross-sectional dimensions

3.4.1 Footings

3.4.1.1 Horizontal dimension of formed members
 + 2 in.
 - 1/2 in.

3.4.1.2 Horizontal dimension of unformed members cast against soil

2 ft. or less + 3 in.
 - 1/2 in.
 Greater than 2 ft. but less than 6 ft + 6 in.
 - 1/2 in.
 Over 6 ft + 12 in.
 - 1/2 in.

3.4.1.3 Vertical dimension (thickness) - 5 percent

3.5 - Relative alignment

3.5.1 Footing side and top surfaces may slope with respect to the specified plane at a rate not to exceed the following amounts in 10 ft 1 in.

SECTION 4 - CAST-IN-PLACE CONCRETE FOR BUILDINGS

4.1 - Vertical alignment

4.1.1 For heights 100 ft or less

Lines, surfaces, and arrises 1 in.
 Outside corner of exposed corner columns and control joint grooves in concrete exposed to view 1/2 in.

4.1.2 For heights greater than 100 ft

Lines, surfaces, and arrises, 1/1000 times the height but not more than 6 in.
 Outside corner of exposed corner columns and control joint grooves in concrete, 1/2000 times the height but not more than 3 in.

4.2 - Lateral alignment

4.2.1 Members 1 in.

4.2.2 In slabs, centerline location of openings 12 in. or smaller and edge location of larger openings . . 1/2 in.

4.2.3 Sawcuts, joints, and weakened plane embedments in slabs 3/4 in.

4.3 - Level alignment

4.3.1 Top of slabs:

4.3.1.1 Elevation of slabs-on-grade 3/4 in.

4.3.1.2 Elevation of top surfaces of formed slabs before removal of supporting shores 3/4 in.

4.3.2 Elevation of formed surfaces before removal of shores 3/4 in.

4.3.3 Lintels, sills, parapets, horizontal grooves, and other lines exposed to view 1/2 in.

4.4 - Cross-sectional dimensions

4.4.1 Members, such as columns, beams, piers, walls (thickness only), and slabs (thickness only)

12 in. dimension or less.. + 3/8 in.
 - 1/4 in.
 More than 12 in. dimension but not over 3 ft dimension + 1/2 in.
 - 3/8 in.
 Over 3 ft dimension + 1 in.
 - 3/4 in.

4.5 - Relative alignment

4.5.1 Stairs

Difference in height between adjacent risers 1/8 in.
 Difference in width between adjacent trends 1/4 in.

4.5.2 Grooves

Specified width 2 in. or less 1/8 in.
 Specified width more than 2 in. but not more than 12 in 1/4 in.

4.5.3 Formed surfaces may slope with respect to the specified plane at a rate not to exceed the following amounts in 10 ft

4.5.3.1 Vertical alignment of outside corner of exposed corner columns and control joint grooves in concrete exposed to view 1/4 in.

4.5.3.2 All other conditions 3/8 in.

4.5.4. The offset between adjacent pieces of formwork facing material shall not exceed:

Class of surface:

Class A 1/8 in.
 Class B 1/4 in.
 Class C 1/2 in.
 Class D 1 in.

4.5.5 Floor finish tolerances shall meet the requirements of either Section 4.5.6 or 4.5.7, as set forth by the specifier.

4.5.6 Floor finish tolerances as measured in accordance with ASTM E 1155-87 Standard Test Method for Determining Floor Flatness and Levelness Using the F-Number System (Inch-Pound Units)

| Floor profile quality classification | Minimum $F_f F_L$ number required | | | |
|--------------------------------------|-----------------------------------|-------------|--------------------------|-------------|
| | Test area | | Minimum local F number | |
| | Flatness F_f | Level F_L | Flatness F_f | Level F_L |
| Conventional | | | | |
| Bullfloated | 15 | 13 | 13 | 10 |
| Straightedged | 20 | 15 | 15 | 10 |
| Flat | 30 | 20 | 15 | 10 |
| Very flat | 50 | 30 | 25 | 15 |

4.5.6.1 The F_L levelness tolerance shall not apply to slabs placed on unshored form surfaces and/or shored form surfaces after the removal of shores. F_L levelness tolerances shall not apply to cambered or inclined surfaces and shall be measured within 72 hr after slab concrete placement.

4.5.7 Floor finish tolerances as measured by placing a freestanding (unleveled) 10 ft. straightedge anywhere on the slab and allowing it to rest upon two high spots within 72 hr after slab concrete placement. The gap at any point between the straightedge and the floor (and between the highspots) shall not exceed:

Classification:

Conventional

Bullfloated 1/2 in.
 Straightedged 5/16 in.

| | |
|-----------------|----------|
| Flat | 3/16 in. |
| Very flat | 1/8 in. |

4.6 - Openings through members

- 4.6.1 *Cross-sectional size of opening.* - 1/4 in.
 + 1 in.
- 4.6.2 *Location of centerline of opening* 1/2 in.

SECTION 5 - PRECAST CONCRETE

5.1 - Fabrication tolerances in linear elements except piles

5.1.1 *Length of member*

| | |
|---------------------------|---------|
| Per 10 ft | 1/8 in. |
| Total not more than | 3/4 in. |

5.1.2 *Cross-sectional dimensions*

| | |
|--------------------------------------|----------|
| 6 in. or less | 1/8 in. |
| Over 6 in. but not over 18 in | 3/16 in. |
| Over 18 in. but not over 36 in | 1/4 in. |
| Over 36 in | 3/8 in. |

5.1.3 *Lateral alignment (sweep) of noncambered member surfaces relative to centerline of member*

Member length

| | |
|-------------------------------------|---------|
| 40 ft and less | 1/4 in. |
| Over 40 ft but not over 60 ft | 3/8 in. |
| Over 60 ft | 1/2 in. |

5.1.4 *Camber variation from design chamber, at time of erection*

| | |
|--|---------|
| For nonprestressed elements, 1/8 in. per 10 ft of length but not more than | 1/2 in. |
| For prestressed elements, 1/4 in. per 10 ft of length but not more than | 1 in. |

5.1.5 *Surface irregularities, deviation from a 10 ft straightedge*

| | |
|---|---------|
| For elements which will not receive topping | 1/4 in. |
| For elements to receive topping | 1/2 in. |
| For elements to be used as concrete guideways support and steering surfaces | 1/8 in. |

5.2 - Fabrication tolerances for piles

- 5.2.1 *Length* + 6 in.
 - 2 in.

5.2.2 *Cross-sectional dimensions*

| | |
|---|----------------------------|
| Overall | 3/8 in. |
| Wall thickness of hollow sections | + 1/2 in. - 0 in. |

5.2.3 *Lateral alignment of pile surfaces relative to pile centerline in length of pile, per 10 ft.* 1/8 in.

5.2.4 *Location of internal void* 3/8 in.

5.2.5 *Pile head*

From the plane perpendicular to the longitudinal axis of pile, 1/4 in. in 12 in. but not more than

| | |
|-------|---------|
| | 1/2 in. |
|-------|---------|

5.2.6 *Surface irregularities*

| | |
|---|---------|
| Pile head | 1/8 in. |
| Other surfaces, deviation from a 10 ft. straight-edge | 1/4 in. |

5.3 - Fabrication tolerances in planar elements

5.3.1 *Length and width*

| | |
|---|------------|
| 10 ft or less | 1/8 in. |
| Over 10 ft but not over 20 ft. | + 1/8 in. |
| | - 3/16 in. |
| Over 20 ft but not over 40 ft. | 1/4 in. |
| Each additional 10 ft increment in excess of 40 ft. | 1/16 in. |
| Difference in length of the two diagonals, of a rectangular member the greater of 1/8 in. per 6 ft of diagonal or | 1/2 in. |

5.3.2 *Cross-sectional dimensions*

| | |
|------------------------|-----------|
| <i>thickness</i> | + 1/4 in. |
| | - 1/8 in. |

5.3.3 *Openings in panels*

| | |
|---|---------|
| Size of opening | 1/4 in. |
| Location of centerline of opening | 1/4 in. |

5.3.4 *Lateral alignment of embedded items*

| | |
|---|---------|
| Reglets for glazing gaskets | 1/8 in. |
| Bolts | 1/4 in. |
| Flashing reglets | 1/4 in. |
| Flashing reglets at panel edge | 1/8 in. |
| Electrical outlets and pipe sleeves | 1/2 in. |
| Weld plates | 1 in. |
| Inserts | 1/2 in. |

5.3.5 *Bowing and warping at time of erection*

Bowing

1/3 60 times the panel diagonal dimension in inches but not more than

| | |
|-------|-------|
| | 1 in. |
|-------|-------|

Warping

1/16 in. per ft. of distance from nearest adjacent corner but not more than

| | |
|-------|-------|
| | 1 in. |
|-------|-------|

5.4 - Erection tolerances

5.4.1 *Vertical, lateral, and level alignment*

5.4.1.1 *Building elements*

Same as for cast-in-place concrete in Section 4.0.

5.4.1.2 *Concrete guideways*

Concrete guideway construction misalignment of support or steering surfaces shall not exceed

| | |
|-------|----------|
| | 1/16 in. |
|-------|----------|

5.4.2 *Alignment of exposed wall panels*

5.4.2.1 *Width of joints between exposed wall panels*

| | |
|-------|---------|
| | 1/4 in. |
|-------|---------|

5.4.2.2 *Taper (difference in width) of joint between adjacent exposed wall panels, the greater of, 1/40 in. per linear foot of joint, or*

| | |
|---------------------|----------|
| | 1/16 in. |
| Not to exceed | 3/8 in. |

5.4.2.3 *Alignment of joints at adjoining corners*

| | |
|-------|---------|
| | 1/4 in. |
|-------|---------|

5.4.2.4 *Offset in exterior face of adjacent panels*

| | |
|-------|---------|
| | 1/4 in. |
|-------|---------|

5.4.3 *Offset of top surfaces of adjacent elements in erected position* ...

| | |
|--|----------|
| With topping slab | 3/4 in. |
| Floor elements without topping slab | 1/4 in. |
| Roof elements without topping slab | 3/4 in. |
| Guideway elements to be used as riding surface | 1/16 in. |

SECTION 6 - MASONRY**6.1 - Vertical alignment**

- In surface of wall 3/4 in.
 In alignment of head joints 1/2 in.

6.2 - Lateral alignment

- 6.2.1 *Vertical members* 1/2 in.

6.3 - Level alignment

- 6.3.1 *In bed joints and top of wall, exposed* 1/2 in.
Not exposed 1 in.
 6.3.2 *Top of wall used for a bearing surface.* . . 1/2 in.
 6.3.3 *Top of wall, other than a bearing surface* 3/4 in.

6.4 - Cross-sectional dimensions

- 6.4.1 *Multivwythed walls* + 1/2 in.
 - 1/4 in.
 6.4.2 *Other members* + 1/2 in.
 1/4 in.
 6.4.3 *Joint thickness* 1/8 in.

6.5 - Relative alignment

- 6.5.1 *Masonry surfaces may slope with respect to the specified plane at a rate not to exceed the following amounts in 10 ft*
 6.5.1.1 *Walls and columns* 1/4 in.
 6.5.1.2 *Bed joints, head joints, and top of wall* 1/4 in.
 6.5.1.3 *Top of wall* 1/4 in.

SECTION 7 - CAST-IN-PLACE, VERTICALLY SLIPFORMED BUILDING ELEMENTS**7.1 - Vertical alignment**

- 7.1.1 *Translation and rotation from a fixed point at the base of the structure:*
 For heights 100 ft. or less 2 in.
 For heights greater than 100 ft., 1/600 times the height but not more than 8 in.

7.2 - Lateral alignment

- Between adjacent elements. 2 in.

7.3 - Cross-sectional dimensions

- Walls + 3/4 in.
 - 3/8 in.

7.4 - Relative alignment

- Formed surfaces may slope with respect to the specified plane at a rate not to exceed the following amount in 10 ft 1/4 in.

SECTION 8 - MASS CONCRETE STRUCTURES OTHER THAN BUILDINGS**8.1 - Vertical alignment**

- 8.1.1 *Surfaces*
 Visible surfaces 1-1/4 in.
 Concealed surfaces 2-1/2 in.
 8.1.2 *Side walls for radial gates and similar watertight joints* 3/16 in.

8.2 - Lateral alignment

- Visible surfaces 1-1/4 in.
 Concealed surfaces 2-1/2 in.

8.3 - Level alignment**8.3.1 General**

- Visible flatwork and formed surfaces 1/2 in.
 Concealed flatwork and formed surfaces . . . 1 in.

- 8.3.2 *Sills for radial gates and similar watertight joints* 3/16 in.

8.4 - Relative alignment

- 8.4.1 *Formed surfaces may slope with respect to the specified plane at a rate not to exceed the following amount in 10 ft*

8.4.1.1 Slopes in lateral and level alignments

- Visible surfaces 1/4 in.
 Concealed surfaces 1/2 in.

8.4.1.2 Slopes in vertical alignment

- Visible surfaces 1/2 in.
 Concealed surfaces 1 in.

SECTION 9 - CANAL LINING**9.1 - Lateral alignment**

- 9.1.1 *Alignment of tangents* 2 in.
 9.1.2 *Alignment of curves* 4 in.
 9.1.3 *Width of section at any height: 0.0025 times specified width W plus one in.* 0.0025W + 1 in.

9.2 - Level alignment

- 9.2.1 *Profile grade* 1 in.
 9.2.2 *Surface of invert* 1/4 in.
 9.2.3 *Surface of side slope* 1/2 in.
 9.2.4 *Height of lining: 0.005 times established height H plus one in.* 0.005H + 1 in.

9.3 - Cross-sectional dimensions

- Thickness of lining cross section: 10 percent of specified thickness provided average thickness is maintained as determined by daily batch volumes.

SECTION 10 - MONOLITHIC SIPHONS AND CULVERTS**10.1 - Lateral alignment**

- 10.1.1 *Centerline alignment* 1 in.
 10.1.2 *Inside dimensions:*
 0.005 times inside dimension

10.2 - Level alignment

- 10.2.1 *Profile grade* 1 in.
 10.2.2 *Surface of invert* 1/4 in.
 10.2.3 *Surface of side slope.* 1/2 in.

10.3 - Cross-sectional dimensions

- 10.3.1 *Cross section at any point*
 Increase thickness: greater of 0.05 times thickness, or + 1/2 in.
 Decrease thickness: greater of 0.25 times thickness, or - 1/4 in.

SECTION 11 - CAST-IN-PLACE BRIDGES**11.1 - Vertical alignment**

- 11.1.1 Exposed surfaces 3/4 in.
 11.1.2 Concealed surfaces 1-1/2 in.

11.2 - Lateral alignment

- Centerline alignment 1 in.

11.3 - Level alignment

- 11.3.1 Profile grade 1 in.
 11.3.2 Top of other concrete surfaces and horizontal grooves
 Exposed 3/4 in.
 Concealed 1-1/2 in.
 11.3.3 Mainline pavements in longitudinal direction, the gap below a 10 ft unlevelled straightedge resting on highspots shall not exceed 1/8 in.
 11.3.4 Mainline pavements in transverse direction, the gap below a 10 ft unlevelled straightedge resting on highspots shall not exceed 1/4 in.
 11.3.5 Ramps, sidewalks, and intersections, in any direction, the gap below a 10 ft unlevelled straightedge resting on highspots shall not exceed 1/4 in.

11.4 - Cross-sectional dimensions

- 11.4.1 Bridge slabs vertical dimension (thickness) + 1/4 in.
 - 1/8 in.
 11.4.2 Members such as columns, beams, piers, walls, and other (slabs thickness only) + 1/2 in.
 - 1/4 in.
 11.4.3 Openings through concrete members .. 1/2 in.

11.5 - Relative alignment

- 11.5.1 Location of openings through concrete members 1/2 in.
 11.5.2 Formed surfaces may slope with respect to the specified plane at a rate not to exceed the following amounts in 10 ft
 Watertight joints 1/8 in.
 Other exposed surfaces 1/2 in.
 Concealed surfaces 1 in.
 11.5.3 Unformed exposed surfaces, other than pavements and sidewalks, may slope with respect to the specified plane at a rate not to exceed the following amounts
 In 10 ft 1/4 in.
 In 20 ft 3/8 in.

SECTION 12 - PAVEMENTS AND SIDEWALKS**12.1 - Lateral alignment**

- 12.1.1 Placement of dowels 1 in.
 12.1.2 Alignment of dowels, relative to centerline of pavement, 18 in. or less projection 1/4 in.
 greater than 18 in. projection
 Not established

12.2 - Level alignment

- 12.2.1 Mainline pavements in longitudinal direction, the gap below a 10 ft unlevelled straightedge resting on

- highspots shall not exceed 1/8 in.
 12.2.2 Mainline pavements in transverse direction, the gap below a 10 ft unlevelled straightedge resting on highspots shall not exceed 1/4 in.
 12.2.3 Ramps, sidewalks, and intersections, in any direction, the gap below a 10 ft unlevelled straightedge resting on highspots shall not exceed. 1/4 in.

SECTION 13 - CHIMNEYS AND COOLING TOWERS**13.1 - Vertical alignment**

Translation, rotation or variance from vertical axis the greater of 1/1000 times the height at time of measurement, or 1 in.

In any 10 ft of height the centerpoint shall not change more than 1 in.

13.2 - Diameter

Outside shell diameter 1/100 times the specified diameter plus 1 in.

13.3 - Wall thickness

The average of four wall thickness measurements taken over a 60 deg arc.

- Specified wall thickness 10 in. or less 1/4 in.
 + 1/2 in.
 Specified wall thickness greater than 10 in. .. 1/2 in.
 + 1 in.

SECTION 14 - NONREINFORCED CAST-IN-PLACE PIPE**14.1 - Wall thickness**

Minimum wall thickness at any point shall be 1/12 times the specified internal diameter of the pipe plus 1/2 in., but in no case less than 2 in.

14.2 - Pipe diameter

The internal diameter at any point shall not be less than 95 percent of the specified diameter, the average of any four measurements taken at 45 deg intervals shall not be less than the specified diameter.

14.3 - Offsets

- At formlaps and horizontal edges shall not exceed:
 For pipe with an internal diameter not greater than 42 in. 1/2 in.
 For pipe with an internal diameter 43 through 72 in. 3/4 in.
 For pipe with an internal diameter greater than 72 in 1 in.

14.4 - Surface indentations

- Maximum allowable 1/2 in.