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

Reported by ACI Committee 117

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This report is a commentary on the Standard Specifications for Tolerances for Concrete Construction and Materials. It is intended to be used with ACI 117 for clarity of interpretation and insight into the intent of the committee regarding the application of the tolerances set forth therein.

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)**.

INTRODUCTION

This commentary pertains to "Standard Specifications for Tolerances for Concrete Construction and Materials (ACI-117)." The purpose of the report is to provide graphic and written interpretations for the specification and its application.

No structure is exactly level, plumb, straight, and true. Fortunately, such perfection is not necessary. Tolerances are a means to establish permissible variation in dimension and location, giving both the designer and the contractor parameters within which the work is to be performed. They are the means by which the designer conveys to the contractor the performance expectations upon which the design is based or the use of the project requires. Such specified tolerances should reflect design assumptions and project needs, being neither overly restrictive nor lenient. Necessity rather than desirability should be the basis of selecting tolerances.

As the title "Standard Specifications for Tolerances for Concrete Construction and Materials (ACI 117)" implies, the tolerances given are standard or usual tolerances that apply to various types and uses of concrete construction. They are based upon normal needs and common construction techniques and practices. Specific tolerances at variance with the standard values can cause both increases and decreases in the cost of construction.

The required degree of accuracy of performance depends on the interrelationship of several factors:

Structural strength and function requirements

The structure must be safe and strong, reflecting the design assumptions, and accurate enough in size and shape to do the job for which it was designed and constructed.

Esthetics

The structure must satisfy the appearance needs or wishes of the owner and the designer.

Economic feasibility

The specified degree of accuracy has a direct impact on the cost of production and the construction method. In general, the higher degree of accuracy required, the higher the cost of obtaining it.

Relationship of all components

The required degree of accuracy of individual parts can be influenced by adjacent units and materials, joint and connection details, and the possibility of the accumulation of tolerances in critical dimensions.

ACI Committee Reports, Guides, Standard Practices, and Commentaries are intended for guidance in planning, designing, executing, or inspecting construction and in preparing specifications. Reference to this document shall not be made in the Project Documents. If items found in these documents are desired to be a part of the Project Documents, they shall be phrased in mandatory language and incorporated in the Project Documents.

*Chairman during initial developement of this document

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Construction techniques

The feasibility of a tolerance depends on available craftsmanship, technology, and materials.

Properties of materials

The specified degree of accuracy for shrinkage and prestressed camber should recognize the degree of difficulty of predetermining deflection due to shrinkage and prestressed camber.

Compatibility

Designers are cautioned to use finish and architectural details that are compatible with the type and anticipated method of construction. Finish and architectural details used should be compatible with the concrete tolerances which are achievable.

Job conditions

Unique job situations and conditions must be considered. The designer must specify and clearly identify those items that require either closer or more lenient tolerances as the needs of the project dictate.

Measurement

Mutually agreed-upon control points and bench marks must be provided as reference points for measurements to establish the degree of accuracy of items produced and for verifying the tolerances of the items produced. Control points and bench marks should be established and maintained in an undisturbed condition until final completion and acceptance of the project.

Project document references

ACI Specification documents—The following American Concrete Institute documents provide mandatory requirements for concrete construction and may be referenced in the Project Documents:

ACI 117	Standard Specifications for Tolerances for Concrete Construction and Materials
ACI 301	Specifications for Structural Concrete for Buildings
ACI 531.1	Specification for Concrete Masonry Construction

ACI informative documents—ACI Committee Reports, Guides, Standard Practices, and Commentaries are intended for guidance in designing, planning, executing, or inspecting construction, and in preparing plans and specifications. Reference to these Reports, Guides, and Standard Practices should not be included in the Project Documents. If the Architect/Engineer desires to include items found in these ACI documents in the Project Documents, they should be rephrased in mandatory language and incorporated into the Project Documents.

The documents of the following American Concrete Institute Committees cover practice, procedures, and state-of-the-art guidance for the categories of construction as listed.

General building	ACI 302, 303, 304, 318, 347
Special structures	ACI 307, 313, 316, 325, 332, 334, 344, 345, 349, 350, 357, 358
Precast construction	ACI 347
Masonry construction	ACI 531
Materials	ACI 211, 223, 302, 304, 315, 318, 531, 543

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Level alignment—See Fig. 1.3.4.
Relative alignment—See Fig. 1.3.5.
Vertical alignment—See Fig. 1.3.6.
Warping—See Fig. 1.3.7.

Level alignment, lateral alignment, and vertical alignment are used to establish a tolerance envelope within which permissible variations can occur. Relative alignment, in addition to designating allowable relative displacements of elements, is used to determine the rate of change of adjacent points (slope tolerance) occurring within the tolerance envelope. In this fashion the slope and smoothness of surfaces and lines within a tolerance envelope are controlled. Abrupt

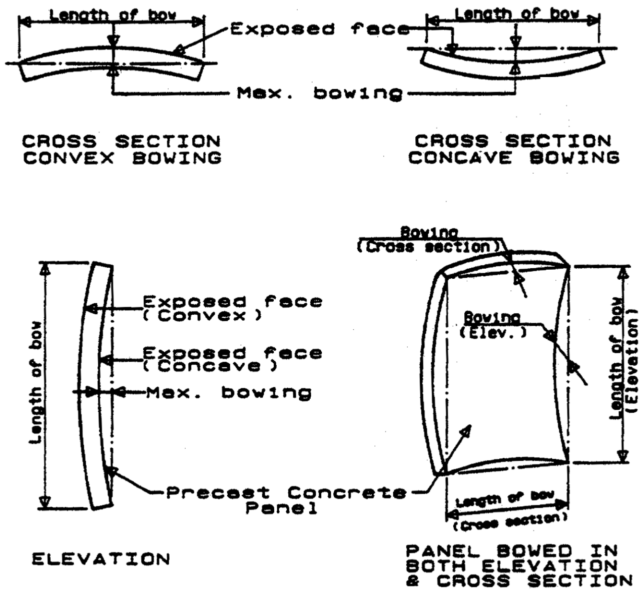

Fig. 1.3.1—Bowing

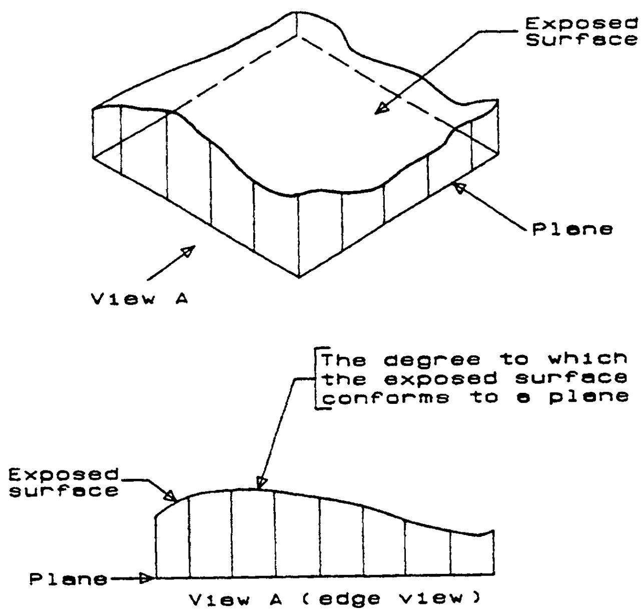

Fig. 1.3.2—Flatness

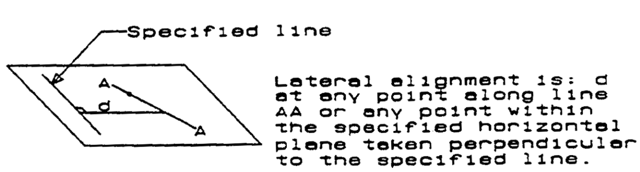

Fig. 1.3.3—Lateral alignment

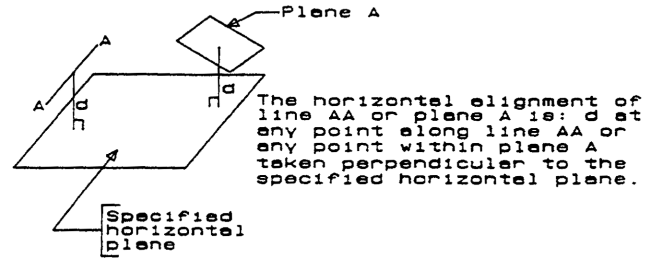

Fig. 1.3.4—Level alignment

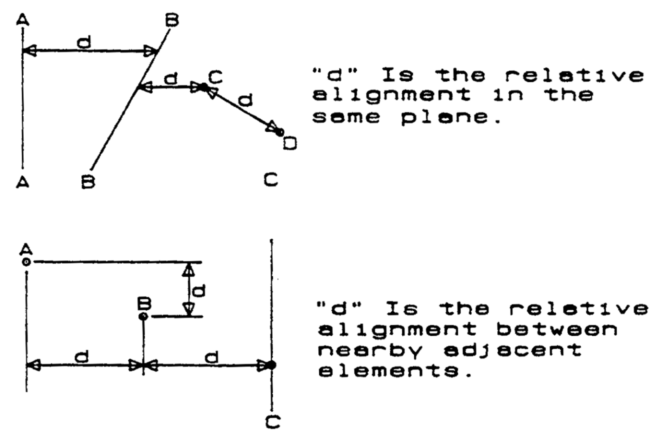

Fig. 1.3.5—Relative alignment

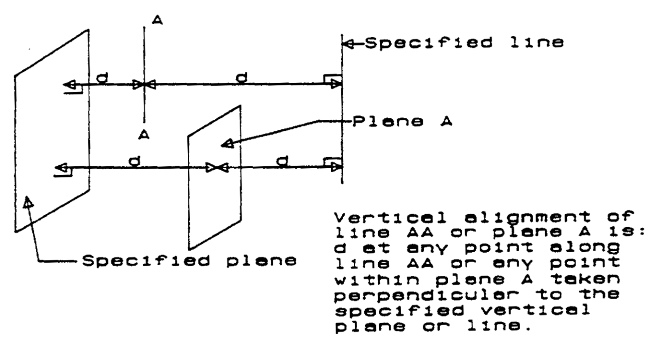

Fig. 1.3.6—Vertical alignment

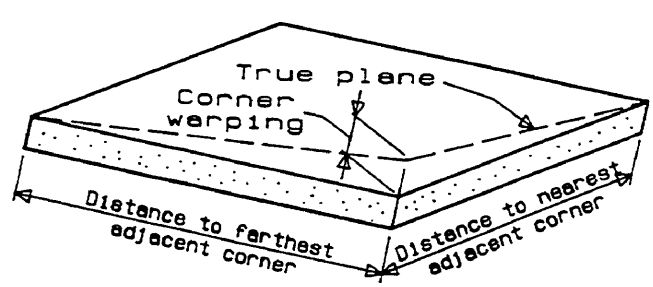

Fig. 1.3.7—Warping

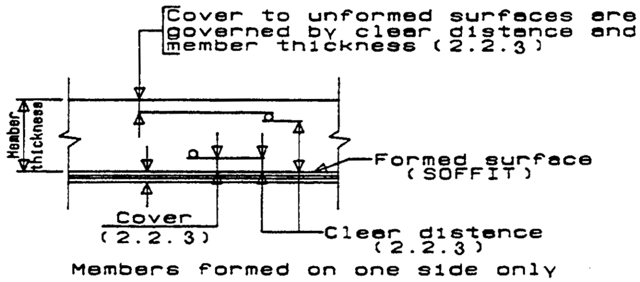

Fig. 2.2.2(a)—Reinforcement placement

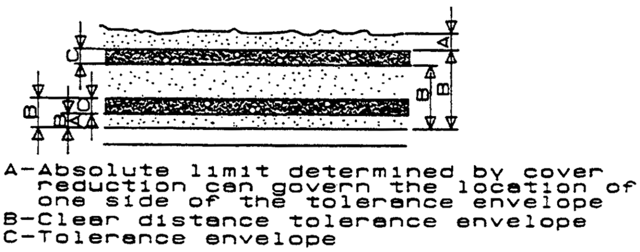

Fig. 2.2.2(b) and 2.2.3(b)—Reinforcement placement

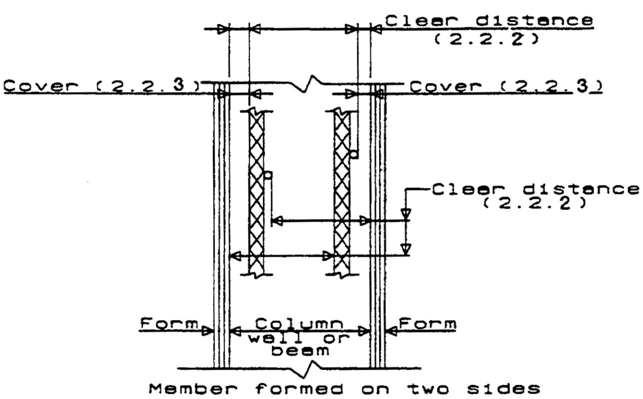

Fig. 2.2.3(a)—Reinforcement placement

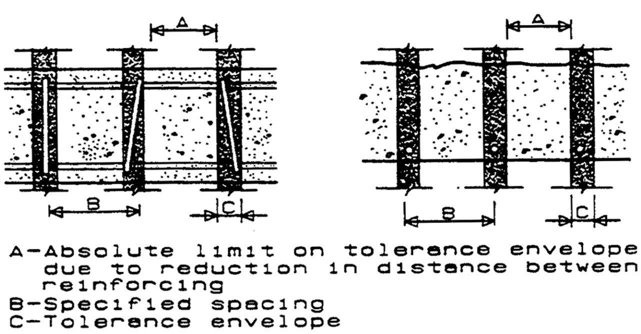

Fig. 2.2.4 and 2.2.5—Reinforcement placement

changes, offsets, sawtoothing, sloping, etc., of lines and surfaces properly located within a tolerance envelope may be objectionable when exposed to view. The acceptable relative alignment of points on a surface or line is determined by using a slope tolerance.

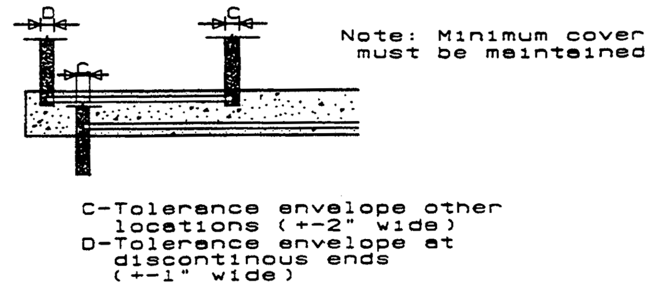

Fig. 2.2.7—Reinforcement placement, longitudinal location

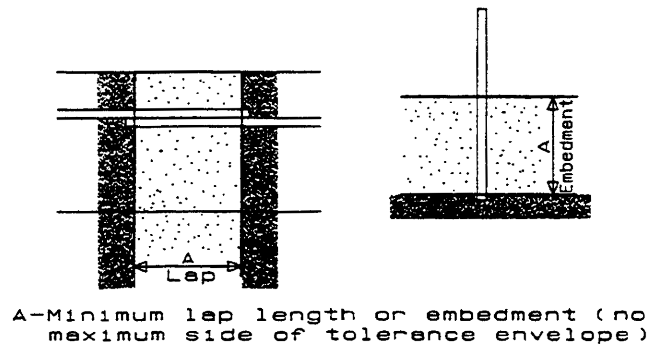

Fig. 2.2.8—Reinforcement placement, embedment and laps

SECTION 2—MATERIALS

2.2—Reinforcement

In the absence of specific design details shown or specified on the contract documents, CRSI MSP-l, Appendix D, should be followed by estimators, detailers, and placers.

2.2.2 and 2.2.3 The tolerance for placing reinforcing steel is predicated upon measurements of the formed surfaces for quality control during construction and from the resulting surfaces for forensic analysis. It consists of an envelope with an absolute limitation on one side of the envelope determined by the limit on the reduction in cover. See Fig. 2.2.2(a), 2.2.2(b), 2.2.3(a), and 2.2.3(b).

2.2.4 and 2.2.5 The spacing tolerance of reinforcing consists of an envelope with an absolute limitation on one side of the envelope determined by the limit on the reduction in distance between reinforcement. In addition, the allowable tolerance on spacing shall not cause a reduction in the specified number of reinforcing bars utilized. See Fig. 2.2.4 and 2.2.5.

2.2.6 The vertical deviation tolerance should be considered in establishing minimum prestressing tendon covers, particularly in applications exposed to deicer chemicals or salt water environments where use of additional cover is recommended to compensate for placing tolerances. Slab behavior is relatively insensitive to horizontal location of tendons.

2.2.7 and 2.2.8 The tolerance for the location of the ends of reinforcing steel is determined by these two sections. See Fig. 2.2.7 and 2.2.8.

2.5—Concrete

2.5.1 Where the specification has specified slump as a maximum, the project specifications should provide for the addition of water at the jobsite for slump adjustment. This is because the concrete must be batched at a lesser slump to avoid rejection because of a lack of a plus tolerance for the slump. The water added at the jobsite must be within the water/cement limitations of the specifications or approved mixture proportions.

Flowable concrete achieved by the incorporation of high range water reducers (HRWR) (superplasticizers), are difficult to control within tight tolerances at specified slumps of 7 in. or greater. In addition, it is difficult to accurately measure high slumps. Consideration should be given to eliminating a maximum slump when a HRWR is used to achieve flowable concrete.

When a slump range is specified, caution should be exercised and jobsite conditions should be considered and evaluated to determined if the range is suitable for delivery and placing requirements.

2.5.2 When an air content range is specified, care should be given to address aggregate size and jobsite requirements. The range should be adequately wide to accommodate the preceding.

SECTION 3—FOUNDATIONS

3.2—Lateral alignment

3.2.1 Determines the permissible location of a footing. The magnitude of tolerance for the location of footings is governed by the width (i.e., least dimension in plan view) of the footing with an absolute limit depending on the subsequent construction material supported by the footing. See Fig. 3.2.1.

3.3—Level alignment

Determines the location of any point on the top surface of a footing relative to the specified plane. See Fig. 3.3.1.

3.4—Cross-sectional dimension

Determines the permissible size of a footing. See Fig. 3.4.

3.5—Relative alignment

The relative alignment of points on the surfaces cannot exceed the distance determined by the slope tolerance. Determines the permissible top surface roughness or irregularity of a footing. See Fig. 3.5.

SECTION 4—CAST-IN-PLACE CONCRETE FOR BUILDINGS

4.1, 4.4, and 4.5—Vertical and relative alignment and thickness

Determines the permissible location of surfaces and lines in a vertical plane and the smoothness of those surfaces or straightness of lines and the relative location of adjacent surfaces in a vertical plane. See Fig. 4.1(a) and (b) and 4.5.3(a) and (b).

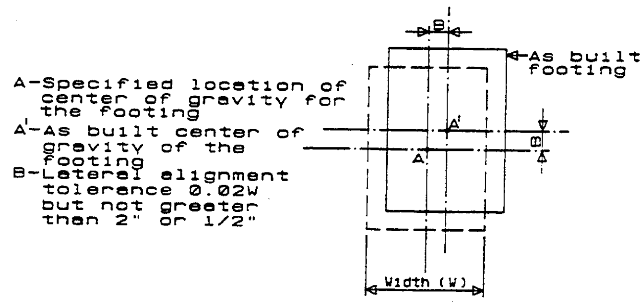

Fig. 3.2.1—Footing lateral alignment

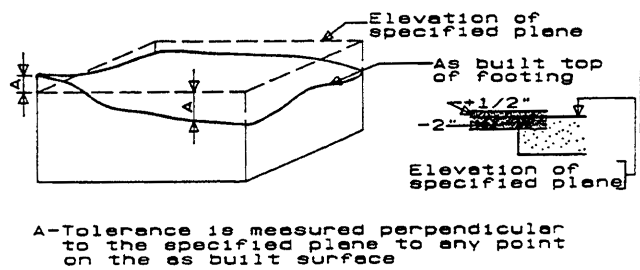

Fig. 3.3.1—Level alignment

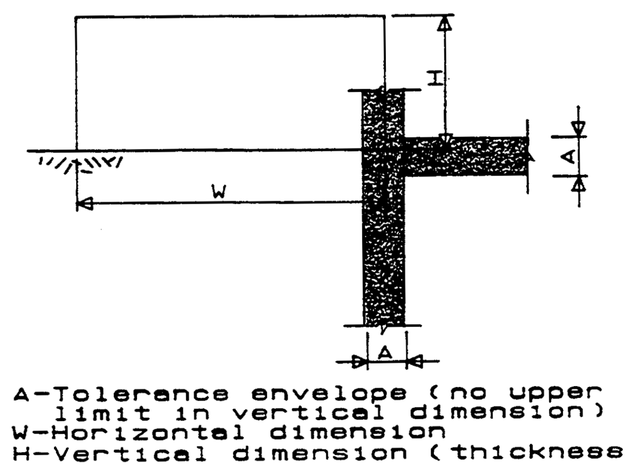

Fig. 3.4—Footing cross-sectional dimension

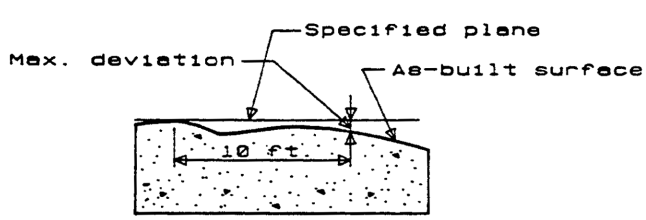

Fig. 3.5—Relative alignment of footing surface

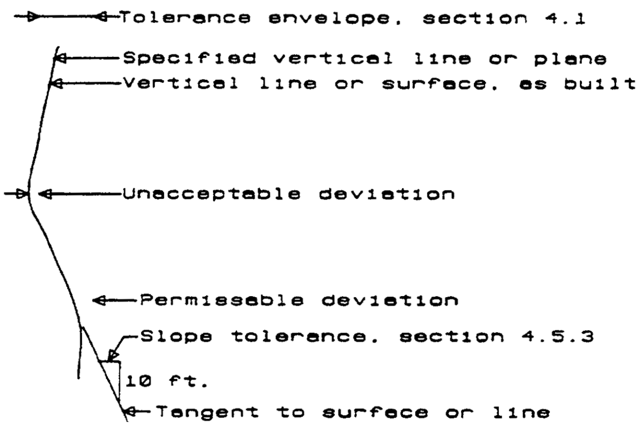

Fig. 4.1(a) and 4.5.3(a)

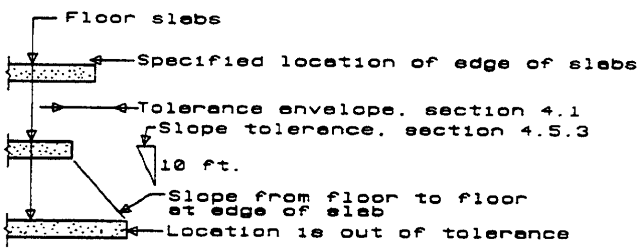

Fig. 4.1(a), (b) and 4.5.3(a), (b)—Vertical and relative alignment

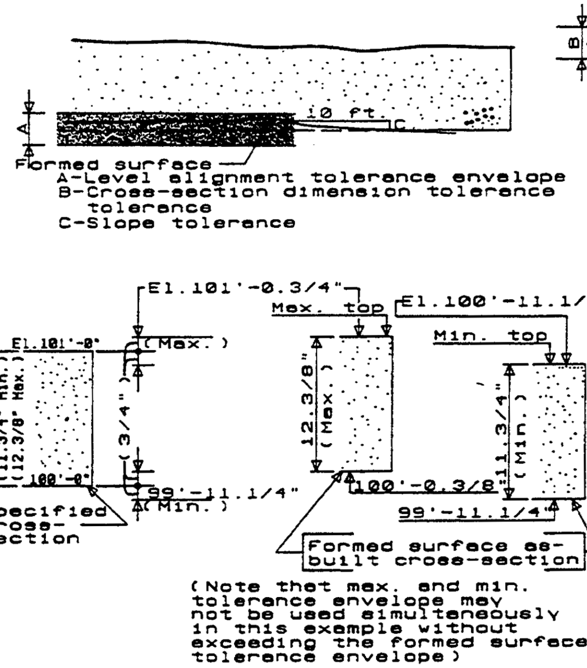

Fig. 4.3, 4.4, and 4.5.3(c)—Level and relative alignment cross-sectional dimension

4.3, 4.4, and 4.5—Level and vertical alignment and cross-sectional dimensions

If the level and cross-sectional dimension tolerances are given, then a suspended (elevated) slab is fully toleranced.

Example: 12 in. slab—The envelope for the slab element extends $^3/_4$ in. above the specified surface elevation to ¼ in. below the specified soffit elevation. Thus the slab surface and/or soffit can be $^3/_4$ in. higher or lower than specified. The slab thickness can be $^3/_8$ in. greater or $^1/_4$ in. less than specified; the rate of change in slope of the top surface is toleranced by the F_L, and the soffit is toleranced by the relative alignment and formed surface tolerances. See Fig. 4.3, 4.4, and 4.5.3 (c).

The acceptable elevation envelope of the slab surface and soffit is ± $^3/_4$ in. The rate of change of the adjacent surface elevation points within the acceptable elevation is governed by specification Section 4.5.5.

4.5.5 Floor profile finish quality has traditionally been measured by limiting the gap to be measured under either a freestanding or leveled 10-ft straightedge, according to the specifier's requirements. The technology for measuring floor profiles has rapidly evolved in response to the needs of random vehicular traffic industrial users. This technology provides a welcome alternative and a solution to the generally recognized inadequacies of the 10-ft straightedge to describe and define floor surfaces. It is not the intention of the ACI 117 specification to limit floor finish measurement technology to that currently available. As new technology is developed, improved, and perfected, specifiers may consider utilizing alternate techniques for specifying and measuring floor finish tolerances. Random sampling and statistical analysis is particularly appropriate for high-performance floors or portions of floors where irregularities must be rigidly controlled.

The specifying of narrow aisle warehouse floors with defined traffic lanes requires specialized techniques not addressed in this specification.

4.5.6 The F_F-F_L system set forth in Section 4.5.6 of this specification provides the specifier, contractor, and owner with a convenient and precise method of communication, measurement, and determination of compliance of the floor surfaces required and achieved, using the procedures set forth in ASTM E 1155. Floor profile quality has traditionally been specified by limiting the size of the gap to be observed under a freestanding or leveled 10 ft long straightedge. However, recent improvements in floor profile measurement technology have surpassed all variations of this "gap-under-the-straightedge" format.[1]

F-numbers provide a convenient means for specifying the local floor profile in statistical terms. Two distinct profile variables are controlled:

- The 12 in. incremental curvature q measures the local *flatness* of the floor. See Fig. 4.5.6(a).
- The 120 in. elevation difference d measures the local *levelness* of the floor. See Fig. 4.5.6(b).

The required data may be gathered by several methods, including measurements taken from leveled straightedges, optical levels, and instruments developed for this purpose.

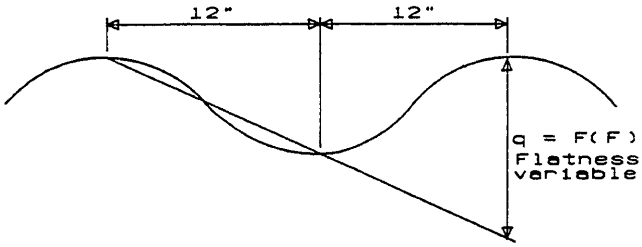

Fig. 4.5.6(a)—Flatness of the floor

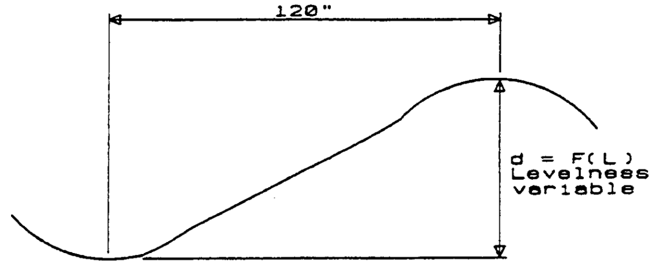

Fig. 4.5.6(b)—Levelness of the floor

Samples of q and d readings are collected from the floor according to the procedures set forth in ASTM E 1155. The means q and d and standard deviations S_q and S_d of these q and d reading samples are calculated, and these statistics are then used to determine the floor's flatness and levelness F-numbers.

Any individual floor section that measures less than either of the specified minimum local F-numbers is rejected. If, after combining all of the individual section results, the entire floor measures less than either of the specified overall F-numbers, then the whole floor is rejected.

To aid in the determination of equitable remedy, the system provides a method for calculating the exact percentage compliance between the floor's specified and estimated F-numbers. To avoid any dispute regarding remedy, the specification should clearly state the specific corrective measures to be applied in the event of an out-of-tolerance result.

Shrinkage, curling, and deflection can all adversely affect floor levelness. Measuring F_L within 72 hr after floor slab installation and before shores and/or forms are removed insures that the floor's "as-built" levelness is accurately assessed. None of the conventional concrete placement techniques in use today can adequately compensate for form or structure deflections that occur during the concrete placement and, for this reason, it is inappropriate to specify levelness tolerances on unshored floor construction.

Since neither deflection nor curling will significantly change a floor's F_F value, there is no time limit on the measurement of this characteristic. Nonetheless, the prudent specifier will provide for the measurement of both F_F and F_L as soon as possible after slab installation to avoid any possible conflict over the acceptability of the floor (and to alert the contractor of the need to modify finishing techniques on subsequent placements if necessary to achieve compliance.)

While there is no direct equivalent between F-numbers and straightedge tolerances (see Fig. 4.5.6c), the following table does give a rough correlation between the two systems:

F-number	Gap under an unleveled 10-ft straightedge
F_F12	1/2 in.
F_F20	5/16 in.
F_F25	1/4 in.
F_F32	3/16 in.
F_F50	1/8 in.

The F-numbers to be obtained using different floor construction methods are given in ACI 302.lR. An increase in flatness from F_F 15 to F_F 20 may generally be achieved by the use of a highway straightedge (or equivalent) rather than a bull-float following the strike-off. The values listed are for general guidance only. Particular job requirements and conditions can result in F-numbers significantly different from those shown.

To insure user satisfaction, the F_F-F_L values required may be determined by measuring successful installations. of projects with similar uses.

Note that ASTM E 1155 excludes measurements within 2 ft of an imbed or a construction joint. The specifier should provide a limitation on the variation and possible offset potential at these locations appropriate to the use and function of the structure.

Other statistical floor tolerancing systems are being developed and may be used at the option of the specifier providing such methods are shown to give comparable results.

IN GENERAL, TO ACHIEVE HIGHER FLOOR FLATNESS/LEVELNESS VALUES WILL REQUIRE MORE INTENSIVE EFFORT WITH ATTENDANT INCREASES IN LABOR AND CONSTRUCTION COSTS.

4.5.7 Although the 10 ft straightedge procedure has been used for more than 50 years for judging floor irregularities, the procedure has a number of serious deficiencies. These include:

- The difficulty in testing large areas of floors.
- The difficulty of randomly sampling floors.
- The inability to reproduce testing results.
- The inability using normal construction procedures to meet the tolerance limits normally specified, that is, 1/8 in. in 10 ft or 1/4 in. in 10 ft and the widespread lack of conformance and lack of testing for conformance of slab surfaces.
- Failure of the method to predict acceptability of irregularities or roughness in the floor surface. The evaluation of the roughness for a given amplitude should be based upon the frequency of the wave forms.[2]
- The inability of the unleveled straightedge to evaluate levelness of the surface.

The major deficiency of the straightedge measuring system in evaluating floor finishes is demonstrated in Fig. 4.5.6(c).

The unleveled straightedge measuring system is adversely affected by shrinkage and curling; therefore, measurements

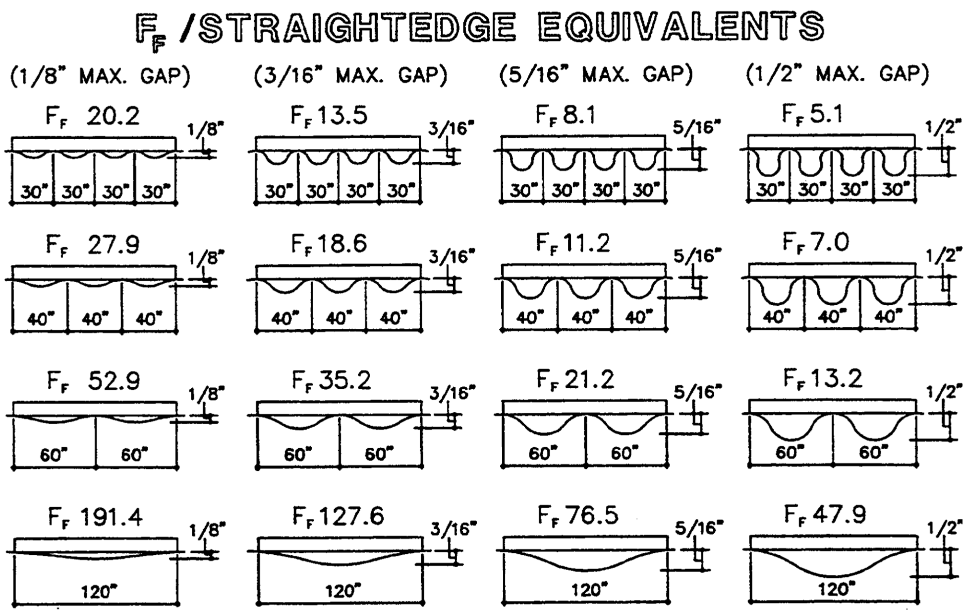

Fig. 4.5.6(c)—F-number system is clearly superior to the "gap under a straightedge" approach for distinguishing between the surfaces of obviously different qualities shown in this diagram

are to be taken within 72 hr after floor slab installation and before shores and/or forms are removed.

SECTION 5—PRECAST CONCRETE

5.0

For guidance and recommended tolerances for precast elements not set forth in ACI 117, the specifier should refer to "Tolerances for Precast and Prestressed Concrete," published in *Journal,* Prestressed Concrete Institute, V. 30, No. 1, Jan.-Feb. 1985, pp. 26 to 112.[3]

5.1—Fabrication tolerances

5.1.1 The fabricated length can be longer or shorter than specified by an amount dependent on its design length with an absolute limit of either 3/4 in. shorter or 3/4 in. longer. See Fig. 5.1.1.

DESIGNERS ARE CAUTIONED TO PROVIDE LONGER BEARING ELEMENTS TO ACCOMMODATE SHORTER MEMBER LENGTHS AND ROOM FOR OVERLENGTH MEMBERS (WITHIN TOLERANCES.)

5.1.3 The lateral alignment is the displacement of any point on the surface relative to the centerline of the as- built member. The centerline is determined by passing a line through the midpoint of the as-built end. See Fig. 5.1.3 and 5.2.3.

5.1.4 Camber is measured at the midpoint between the as-built ends of the member. The allowable deviation is a function of the length of the member with an absolute limit. Camber tolerances in prestressed members may require reevaluation after initial member castings due to the inaccuracies inherent in initial engineering predications based upon the member design. The specified camber may require adjustment based upon the actual camber that results from the specified design or the design may require modification. See Fig. 5.1.4.

5.1.5 *Surface irregularities*—See Fig. 5.1.5.

5.2—Fabrication tolerances for piles

5.2.3 Tolerance determination is similar to Section 5.1.1. The exception is that there is no absolute limit applied to the tolerance envelope.

5.2.5 The slope across the pile head can vary as a function of the width of the pile head with an absolute limit. The width is the diameter of circular piles and the cross-sectional dimension in the direction of slope measurement of noncircular piles. See Fig. 5.2.5.

5.3—Fabrication tolerances in planar elements

5.3.1 The allowable skew of planar elements is determined by comparing the length of the diagonals. This pre-presumes rectangular units for the application of this fabrication control. For irregularly shaped units the comparison of diagonals may not be possible or meaningful and the concept of skew may not apply. See Fig. 5.3.1.

5.4—Erection tolerances

5.4.2.2 The allowable taper of the joint between exposed panels is a function of the length of the joint with absolute limits on the minimum and maximum width of the tolerance envelope. See Fig. 5.4.2.2.

5.4.3 The control over the offset of top surfaces of adjacent elements applies to members immediately adjacent to each other or separated members that will ultimately be joined in the structure (see Fig 5.4.3). The roofing system must be coordinated with the tolerance for roof elements without topping slabs. Roofing systems that are to be applied directly to the precast surface may require a leveling grout to fill and feather the resulting offset.

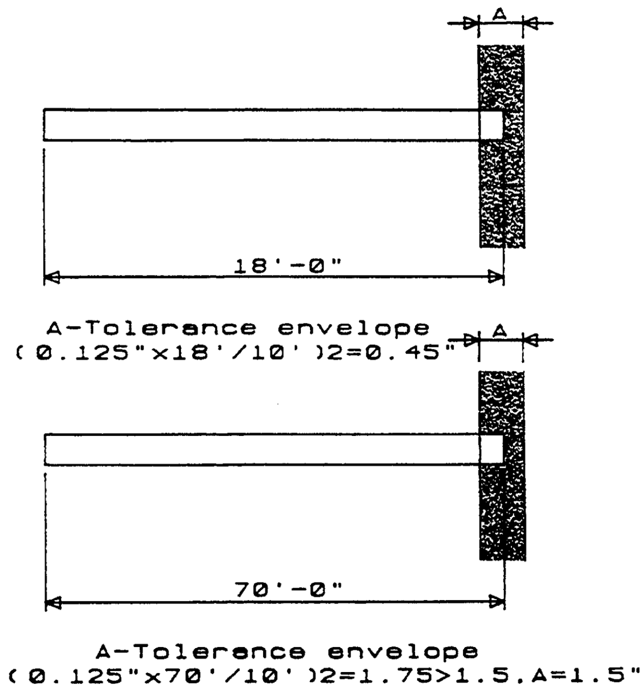

Fig. 5.1.1—Length of member

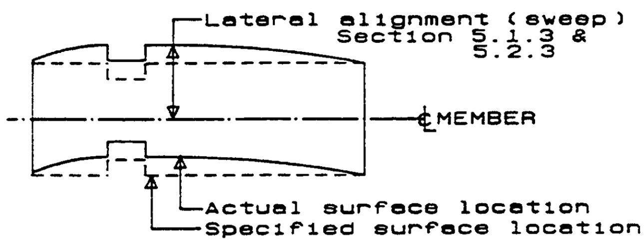

Fig. 5.1.3 and 5.2.3—Lateral alignment

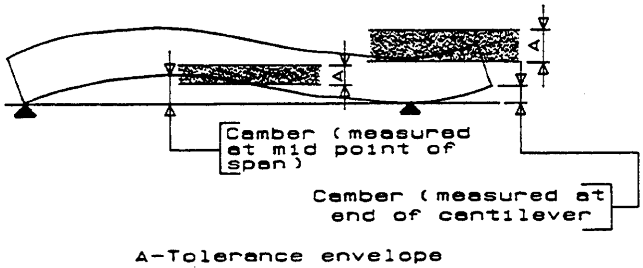

Fig. 5.1.4—Camber

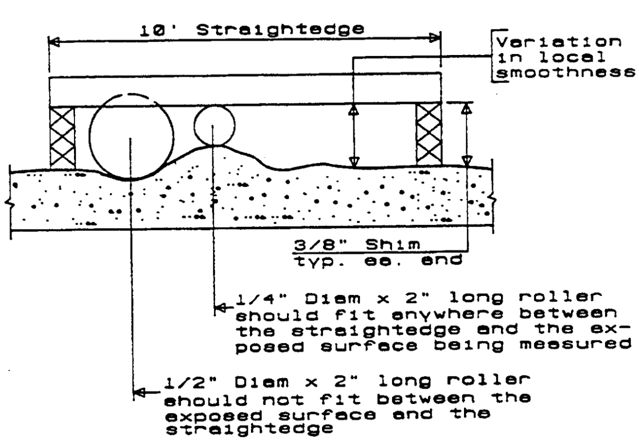

Fig. 5.1.5—Surface irregularities

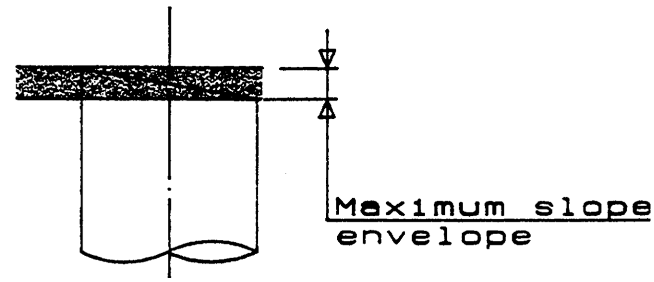

Fig. 5.2.5—Pile head

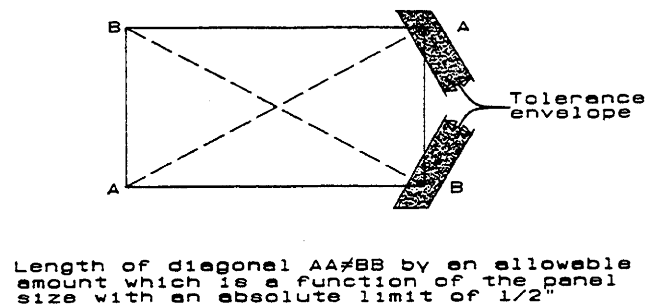

Fig. 5.3.1—Panel length and width

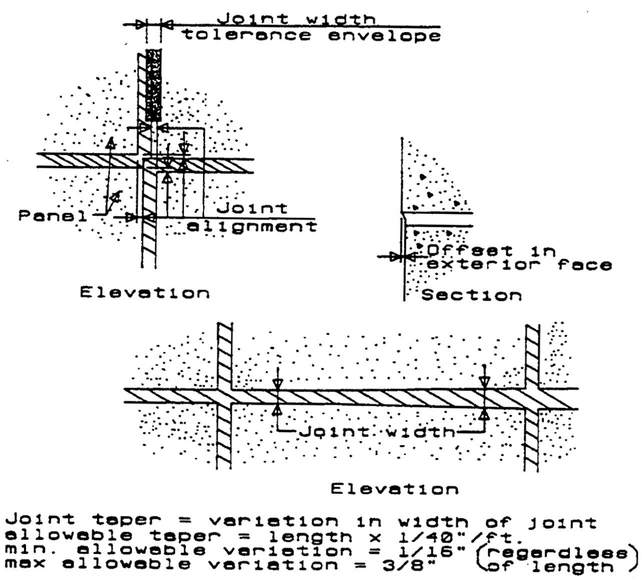

Fig. 5.4.2.2—Alignment of panels

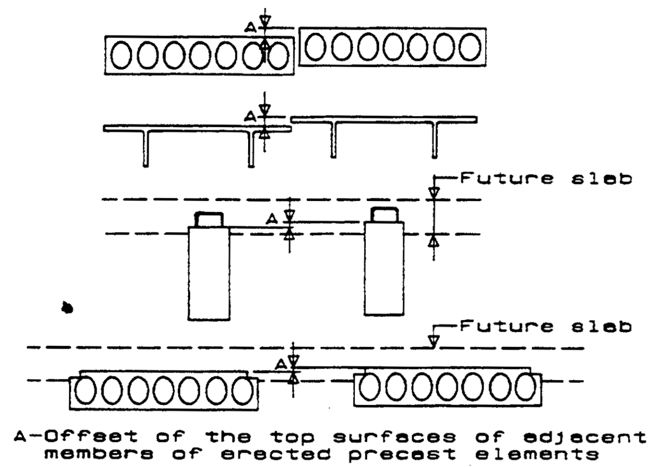

Fig. 5.4.3—Difference in elevation

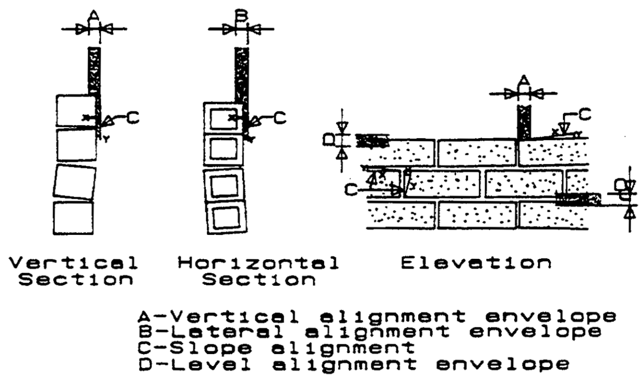

Fig. 6.1, 6.2, 6.3, and 6.5—Masonry alignment

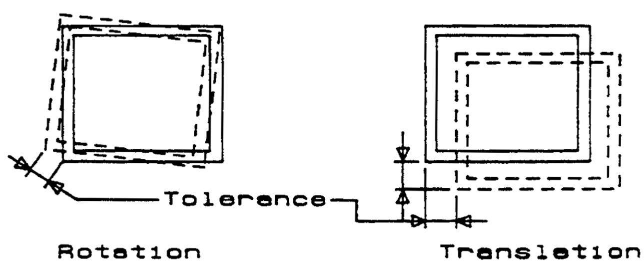

Fig. 7.1—Slipform vertical alignment

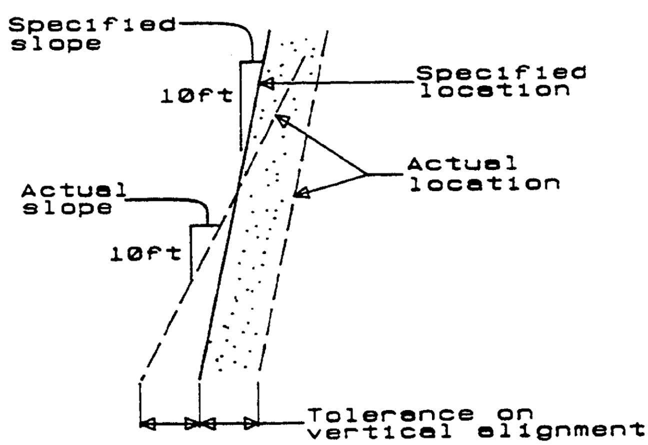

Fig. 11.1 and 11.5.2—Vertical section

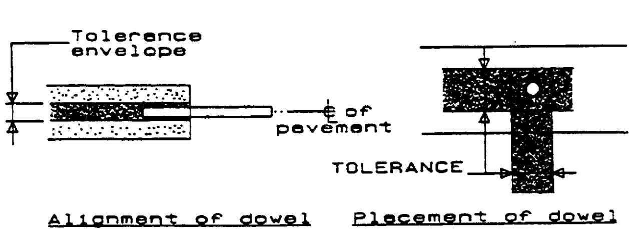

Fig. 12.1—Pavement dowels

SECTION 6—MASONRY

6.1, 6.2, 6.3, and 6.5—Alignments

See Fig. 6.1., 6.2, 6.3, and 6.5.

SECTION 7—CAST-IN-PLACE, VERTICALLY SLIPFORMED BUILDING ELEMENTS

7.1—Vertical alignment

See Fig. 7.1.

7.2, 7.3, and 7.4

Refer to the commentary in Section 4.

SECTION 8—MASS CONCRETE STRUCTU RES OTHER THAN BUILDINGS

8.1, 8.2, 8.3, and 8.4

Refer to the commentary in Section 4.

SECTION 9—CANAL LINING

9.1, 9.2, and 9.3

Refer to the commentary in Section 4.

SECTION 10—MONOLITHIC SIPHONS AND CULVERTS

10.1, 10.2, and 10.3

Refer to the commentary in Section 4.

SECTION 11—CAST-IN-PLACE BRIDGES

11.1, 11.2, 11.3, 11.4, and 11.5

Refer to the commentary in Section 4. See Fig. 11.1 and 11.5.2.

SECTION 12—PAVEMENT

12.1—Lateral alignment

12.1.1 *Placement of dowels*—See Fig. 12.1.

SECTION 13—CHIMNEYS AND COOLING TOWERS

13.1 Tolerances on the size and location of openings and embedments in the concrete shell cannot be uniformly established due to the varying degree of accuracy required depending on the nature of their use. Appropriate tolerances for opening and embedment sizes and locations should be established for each chimney.

SECTION 14—CAST-IN-PLACE NONREINFORCED PIPE

14.1 Cast-in-place concrete pipe tolerances relate to the accuracy of construction that can be achieved with tracked excavators.

SECTION 15—REFERENCES

15.1—Recommended references

The documents of the various standards producing organizations referred to in this document are listed below with their serial designation.

American Concrete Institute

211.1-81 (Revised 1985)	Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete
223-83	Standard Practice for the Use of Shrinkage-Compensating Concrete
302.1R-80	Guide for Concrete Floor and Slab Construction
303R-74 (Revised 1982)	Guide to Cast-in-Place Architectural Concrete Practice
304R-85	Guide for Measuring, Mixing, Transporting, and Placing Concrete
307-88	Design and Construction of Cast-in-Place Reinforced Concrete Chimneys
313-77 (Revised 1983)	Recommended Practice for Design and Construction of Concrete Bins, Silos, and Bunkers for Storing Granular Materials
315-80	Details and Detailing of Concrete Reinforcement
316R-82	Recommendations for Construction of Concrete Pavements and Concrete Bases
318R-83	Commentary on Building Code Requirements for Reinforced Concrete (318-83)
325.3R-85 (Revised 1987)	Guide for Design of Foundations and Shoulders for Concrete Pavements
332R-84	Guide to Residential Cast-in-Place Concrete Construction
334.1R-64 (Revised 1982) (Reapproved 1986)	Concrete Shell Structures-Practice and Commentary
344R-W	Design and Construction of Circular Wire and Strand Wrapped Prestressed Concrete Structures
344R-T	Design and Construction of Circular Prestressed Concrete Structures with Circumferential Tendons
345-82	Standard Practice for Concrete Highway Bridge Deck Construction
347-78 (Reapproved 1984)	Recommended Practice for Concrete Formwork
349R-85	Commentary on Code Requirements for Nuclear Safety Related Concrete Structures
350R-83	Concrete Sanitary Engineering Structures
357R-84	Guide for the Design and Construction of Fixed Offshore Concrete Structures
358R-80	State-of-the-Art Report on Concrete Guideways
531R-79 (Revised 1983)	Commentary on Building Code Requirements for Concrete Masonry Structures
531. 1-76 (Revised 1983)	Specifications for Concrete Masonry Construction
543R-74 (Reapproved 1980)	Recommendations for the Design, Manufacture, and Installation of Concrete Piles

ASTM

E1155-87	Standard Test Method for Determining Floor Flatness and Levelness Using the F-Number System (Inch-Pound Units)

Concrete Reinforcing Steel Institute

MSP-l-86	Manual of Standard Practice (24th Edition)

The preceding publications may be obtained from the following organizations:

American Concrete Institute
P.O. Box 9094
Farmington Hills, MI 48333-9094

ASTM
1916 Race Street
Philadelphia, PA 19103

Concrete Reinforcing Steel Institute
933 North Plum Grove Road
Schaumburg, IL 60173-4758

15.2—Cited references

1. Face, Allen, “Specification and Control of Concrete Floor Flatness,” *Concrete International: Design & Construction,* V. 6, No. 2, Feb. 1984, pp. 56-63.

2. Hudson, W. Ronald; Halbach, Dan; Zaniewski, John P.; and Moser, Len, “Root-Mean-Square Vertical Acceleration as a Summary Roughness Statistic,” *Measuring Road Roughness and its Effect on User Cost and Comfort,* STP-884, pp. 20-21.

3. PCI Committee on Tolerances, “Tolerances for Precast and Prestressed Concrete,” *Journal,* Prestressed Concrete Institute, V. 30, No. 1, Jan.-Feb. 1985, pp. 26-112.

This report was submitted to letter ballot of the committee and was approved in accordance with the Institute’s balloting procedures.