Tolerance incompatibility problems increase cost and have an adverse effect on construction schedules. Examples of such problems include embedment plates that aren’t properly located for welding the structural steel connections, concrete floors that aren’t flat enough for installation of the specified floor covering, and gross opening dimensions that are too small for mounting the specified window or curtain wall units. All of these problems occur at the interface of construction elements placed by different subcontractors, and many are avoidable.

**OPTIONS FOR DEALING WITH TOLERANCE CONFLICTS**

Tolerances for product manufacture, erection, joints, and interfaces with other construction materials must be carefully considered for all materials so tolerance variations can be accommodated if necessary. Tolerance-accommodating details, which in some cases allow very significant tolerance variations to be appropriately handled, may be needed. When there are tolerance compatibility problems involving different subcontractors, resolution of the problems can include some of the following options:

- Modify the tolerance that will solve the problem at the lowest cost;
- Modify connection details to accommodate the different tolerances;
- Modify the tolerance that has the smallest impact on the schedule; and/or
- Modify tolerances that least affect the finished product provided to the owner.

Following are some common tolerance compatibility issues and suggested resolutions for them.

**Issue:** ACI 117-90 gives different placement tolerances for nonprestressed and prestressed reinforcement. Tolerances for placing prestressed reinforcement are tighter.

**Industry practice:** Prestressed strands are positioned by tying them to the in-place reinforcing bars, resulting in the strands not being placed within the required tolerance.

**Suggested resolution:** Make nonprestressed and prestressed reinforcement placing tolerances identical. This can be justified because current industry practice has resulted in satisfactory performance of both pre- and post-tensioned concrete members for more than 20 years.

**Issue:** Slab thickness tolerances are given in ACI 117-90, but minimum slab thickness for fire resistance is given in ACI 216R-89, “Guide for Determining Fire Endurance of Concrete Elements.” Building officials measure slab thickness for fire resistance and hold to this “minimum” without a tolerance.

**Industry practice:** A slab thickness selection based on ACI 216R-89 requirements is rarely specified as “minimum” on the drawings or in the specifications. ACI 301-99, “Specifications for Structural Concrete,” which references ACI 117-90, is cited in many contract documents. Thickness tolerances apply to all slabs.
Everyday Issues

**Suggested resolution:** The safety factor inherent in fire resistance testing is adequate to allow a tolerance for slab thicknesses required by ACI 216R-89. ACI Committee 216 could consider adding a sentence to the document indicating that ACI 117-90 tolerances are applicable.

**Issue:** Steel erectors often state that anchor bolt placements by concrete contractors don’t comply with the steel erectors’ tolerances and request modification at the concrete contractors’ expense. Or the steel erector submits a claim for the additional cost to erect the steel.

**Industry practice:** Division 3 specifications for cast-in-place concrete reference ACI 117-90, which doesn’t mention anchor bolts. But Section 2.3 of ACI 117-90 refers to placement of embedded items and requires a ±1 in. (25 mm) tolerance for vertical, lateral, and level alignment. Division 5 specifications for structural steel reference the American Institute of Steel Construction (AISC) Code of Standard Practice for Steel Buildings and Bridges. AISC states that the variation in dimension between the centers of any two anchor rods within an anchor rod group shall be equal to or less than 1/8 in. (3 mm). The concrete and steel tolerances, which are considerably different but are both included in the contract documents, often lead to a dispute between subcontractors (Fig. 1). That dispute is refereed by the general contractor or construction manager who generally seeks to avoid passing the cost for correcting the situation to the owner.

**Suggested resolution:** The American Society of Concrete Contractors (ASCC) Position Statement No. 14, “Anchor Bolt Tolerances,” suggests tolerances that are tighter than those of ACI but not as tight as the AISC tolerances. A proposed revision of ACI 117 incorporates these suggested ASCC tolerances. Specifiers can cite these tolerances in both Division 3 and Division 5 to ensure that the concrete contractor and steel erector are using the same tolerance.

**Issue:** Weld plates are embedded in cast-in-place concrete to provide connections to steel members. ACI and AISC have different tolerances for the required weld plate positioning.

**Industry practice:** ACI 117-90 uses ±1 in. (25 mm) for vertical, lateral, and level alignment of embedded items. AISC states that “embedded items and connection materials that are part of the work of other trades, but that will receive Structural Steel, shall be located and set by the Owner’s Designated Representative for Construction in accordance with an approved Embedment Drawing. The variation in location of these items shall be limited to a magnitude that is consistent with the tolerances that are specified in Section 7.13 for the erection of Structural Steel.”

**Suggested resolution:** Connections are usually detailed to accommodate positioning of weld plates. This should be checked before construction because not all engineers consider weld plate positioning when detailing connections. Concrete contractors have difficulty interpreting AISC weld-plate tolerances because there isn’t a particular dimension associated with those tolerances. Consider using ACI 117-90 weld-plate tolerances in both Division 3 and 5 specifications, increasing the size of the weld plate, or doing both.

![Fig. 1: Comparison of ACI 117-90 and AISC tolerances for anchor bolt locations. Note: 1 in. = 25.4 mm.](image)

**WORKING GROUP ON TOLERANCE INCOMPATIBILITY ISSUES**

The American Society of Concrete Contractors (ASCC) is organizing and hosting an Inter-Industry Working Group meeting on “Reducing the Cost of Construction Tolerance Incompatibility Issues.” The day-and-a-half meeting is being cosponsored by several construction-related organizations including the American Concrete Institute. It will be held Thursday and Friday, February 17-18, 2005, at the Marriott Renaissance St. Louis Airport Hotel.

The meeting registration fee is $200, which covers dinner and lunch functions plus handouts that will include background information, articles, and notes from speakers’ presentations. Attendees will also receive a copy of the meeting “Summary Report” to be written and distributed after the meeting. For more information, call ASCC at (314) 962-0210 or visit their website at [www.ascconline.org](http://www.ascconline.org).
**Everyday Issues**

**Issue:** Specifications require a smooth-form concrete wall finish but also require application of paint or other coatings.

**Industry practice:** For a smooth-form finish, ACI 301-99 requires patching of tie holes and defects, and removal of fins that exceed 1/8 in. (about 3 mm) in height. Although there is no reference to an allowable number or size of bugholes in ACI 301-99, some bugholes can be expected. The term “smooth-form finish” suggests that the surface can be painted or coated without further treatment, but coating applicators often request additional surface preparation of bugholes, patches, and fins—even fins less than 1/8 in. (about 3 mm) in height. Responsibility for the cost of additional surface preparation isn’t clearly defined.

**Suggested resolution:** Coordinate the specified concrete surface with the paint or coating applicator’s requirements. These requirements often result in the need for a rubbed finish, which the concrete contractor needs to know before bidding the project. The paint or coating applicator should know of the concrete surface finish specified for the concrete contractor and, most importantly, the characteristics of the specified surface finish.

**Issue:** Plasterers have to use more material and labor than they anticipated when bidding a project because they expected the concrete-wall substrate to be “true, even and plane.”

**Industry practice:** ACI 117-90 requires the relative alignment for a concrete wall to be 3/8 in. in 10 ft (about 3 mm/m) or better. Plaster specifications reference ASTM C 926, “Standard Specification for Application of Portland Cement-Based Plaster,” which requires the concrete surface to be within 1/4 in. in 10 ft (about 2 mm/m). These conflicting requirements can be the basis for a dispute about who pays the plasterer for the extra work.

**Suggested resolution:** Plaster specification should state that the concrete wall tolerance for relative alignment is 3/8 in. in 10 ft (about 3 mm/m). Plastering contractors can then take that relative alignment tolerance into account when submitting their bid.

**Issue:** An elevator installer indicates support rails won’t fit and must be modified because the concrete wall placement doesn’t meet the installer’s vertical alignment tolerances.

**Industry practice:** The ACI 117-90 vertical alignment tolerance is 1 in. for concrete wall heights less than 100 ft (about 25 mm for wall heights less than 30 m) and 1/1000 times the height but not to exceed 6 in. for walls exceeding 100 ft tall (not to exceed about 150 mm for walls exceeding 30 m). The National Elevator Industry requires a clear hoistway, plumb from top to bottom, with variations not to exceed 1 in. at any point in the first 100 ft (about 25 mm at any point in the first 30.5 m). Tolerance may increase at 1/32 in. (about 0.8 mm) for each additional 10 ft (3 m) up to a maximum displacement of 2 in. (50 mm). Minimum required hoistway opening dimensions are sometimes shown in elevator manufacturers’ drawings. Using these minimum dimensions doesn’t permit any concrete wall tolerance that makes the opening smaller. The National Elevator Industry maximum tolerance of 2 in. (50 mm) is certainly at odds with the ACI 117-90 maximum of 6 in. (150 mm).

**Suggested resolution:** Oversize the manufacturer’s minimum opening dimensions by at least 2 in. (50 mm) in each direction. Elevator installers can use larger support rails.

**SPECIFIC GUIDANCE IS NEEDED**

“Guide to Formwork for Concrete (ACI 347-01)” states, “The engineer/architect should be responsible for coordinating the tolerances for concrete work with the tolerance requirements of other trades whose work adjoins the concrete construction.” The “Commentary on Standard Specifications for Tolerances for Concrete Construction and Materials (ACI 117-90)” states, “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.”

Neither ACI 347-01 nor ACI 117-90 contains specific guidance for the tolerance coordination that’s needed before contract documents are prepared and construction begins. Lessons from tolerance incompatibility issues—especially those involving different trades—are typically learned as a result of experience on a project. And this learning experience can be costly. In today’s competitive bidding market, construction work is often completed by many subcontractors, thus requiring more tolerance coordination than in the past. Whereas subcontractors were formerly willing to “just take care of these things,” lower profit margins have made them less willing to pay the cost of fixing problems caused by tolerance incompatibility issues.
brackets to support the elevator rails, but can’t do much when the opening is too small. Coordinate concrete tolerances with the elevator selection.

**Issue:** The Americans with Disabilities Act (ADA) states that all dimensions for structures covered by ADA requirements are subject to conventional building industry tolerances for field conditions.

**Industry practice:** The ADA typically specifies minimum and maximum dimensions and slopes for ramps and sidewalks. ACI 117-90 doesn’t include tolerances for sloped surfaces, although proposed tolerances have been published. The industry is currently attempting to resolve this issue.

**Suggested resolution:** The easiest resolution is adoption of California’s Orange Empire ICBO Chapter recommendations for use in the project specifications. Don’t specify any slopes or dimensions at the ADA mandated minimum or maximum because that reduces the possible construction tolerance by one-half.

**Issue:** Concrete floor finish tolerances specified in Division 3 don’t match those specified in Division 9 for floor coverings.

**Industry practice:** In Division 3, engineers specify F-numbers to be measured in accordance with ASTM E 1155, “Standard Test Method for Determining F, Floor Flatness and F, Floor Levelness Numbers.” Measurements are taken within 72 h of concrete placement and no measurements are taken within 2 ft (0.6 m) of any construction joints or penetrations. In Division 9, architects specify floor flatness requirements as a gap under a 10 ft (3 m) straightedge to be measured anywhere on the floor and at any time. The floor flatness requirements can vary with the type of floor covering—carpet, vinyl composition tile, hardwood, ceramic tile or other—but the floor covering sometimes isn’t chosen until after the concrete floor has been placed. Because of the difference in measuring systems (F-numbers versus gap under 10 ft straightedge) and the change in floor flatness with time due to curling (Fig. 2), the floor placed by the concrete contractor often doesn’t meet the needs of the floor covering installer. Construction managers or general contractors may try to have either the concrete subcontractors or floor covering pay the cost of making the concrete floor suitable for the floor covering.

**Suggested resolution:** Recognize that concrete floor flatness will change with time and that, for the foreseeable future, different floor-flatness measuring systems will be used by the concrete contractor and flooring installer.

One option is to provide a bid allowance to the floor covering contractor for any grinding or patching needed to create a surface suitable for flooring installation. If no grinding is required because the floor flatness doesn’t change with time, the owner retains the money. Other options are given in Reference 14.

**Issue:** Prefabricated full-height metal curtain wall panels don’t fit when installed between the concrete floors.

**Industry practice:** Level alignment tolerance for the top of concrete floors and bottom of concrete surfaces supported by forming is ±3/4 in. (20 mm). Floor-to-ceiling metal curtain walls or partitions must have connection details that allow for an opening that is about 1-1/2 in. (38 mm) larger or smaller than the plan dimensions. The larger opening can often be accommodated, but a smaller opening may require concrete removal to permit wall or partition installation.

**Suggested resolution:** Provide a connection detail that accommodates a ±1-1/2 in. (38 mm) variation in the dimensions of the opening and size the curtain wall accordingly. Coordinate this detail with the architect and curtain-wall installer.

**Issue:** Project specifications require a level surface for concrete slabs placed on metal decking supported by structural steel shapes, open web steel joists, or precast members.

**Industry practice:** For concrete slabs placed on metal decking supported by structural steel shapes or open web steel joists, the extra concrete needed in the middle of the bay to make the concrete floor level may be 3/4 in. (18 mm) or more. Adding extra concrete to satisfy the
level requirement results in a slab thickness that exceeds the +3/8 in. (about 10 mm) tolerance of ACI 117-90. Designers who specify level surfaces for concrete topping slabs on cambered precast panels or tees should also be aware that the topping thickness will be greater at the ends of the members. At openings, stairs or other prefabricated items may not fit because the thicker concrete topping increases finish slab elevation.

**Suggested resolution:** State that the plus thickness tolerance does not apply for concrete slabs placed on metal decking and supported by structural steel shapes or open web steel joists. Verify that thicker slabs don’t add more weight to columns or foundations than is allowable. When toppings are required for precast/prestressed members, consider the effect of thicker slabs at openings to ensure that prefabricated items such as stairs will still fit.

**References**

16. CRSI, “Construction Tolerance Conflicts in Reinforced Concrete,” Engineering Data Report No. 40, Concrete Reinforcing Steel Institute, Schaumburg, IL.

Selected for reader interest by the editors.

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