

## Measuring Flatness of Elevated Floors

**Q.** *As a concrete contractor, I'm dealing with a problem related to floor flatness of an elevated slab. The general contractor (GC) surveyed the elevated slab 20 days after the first placement and 5 days after the second—all of which was after tensioning of tendons and partial removal of shoring. The GC is trying to hold me accountable for 1/4 in. in 10 ft (6 mm in 3 m) tolerance when the survey cut sheet is showing as much as 3/4 in. (19 mm) positive deviation from floor flatness ( $F_f$ ) elevation. Can I dispute that the slab  $F_f$  meets the  $\pm 3/4$  in. deviation from the elevation limit for formed suspended slabs provided in Section 4.4.1 of ACI 117-10(15)?*

**A.** This question comes up regularly but is clearly answered in ACI 117-10(15). ACI 117-10(15) includes a full six pages (from Section 4.8.4 to 4.8.7) of specification and commentary covering random traffic floor surface finish tolerances. Several techniques for measuring the flatness (bumpiness) are included to describe the degree to which a floor surface is smooth or plane.

It sounds as though your specific project had a flatness requirement of 1/4 in. in 10 ft measured using the manual straightedge method. Commentary Section R4.8.4 in ACI 117-10(15) includes Table R4.8.4, which provides a rough relationship between the manual straightedge method and the statistical  $F_f$  method based on a study of six groups of 100 individual profiles each (600 total). A requirement of 1/4 in. in 10 ft roughly equates to a specified overall floor flatness ( $SOF_f$ ) ranging from 24.0 to 45.9, which is in the “Flat” floor classification. Whichever method is used, the testing must be completed within 72 hours of final finishing and before the removal of any shores, as specified in Section 4.8.4.4 of ACI 117-10(15):

“Floor test surfaces shall be measured and reported within 72 hours after completion of slab concrete finishing operations and before removal of any supporting shores.”

As stated in Commentary Section R4.8.4.4, “The purpose for establishing a default 72-hour time limit on the measurement of floor surfaces is 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.”

All slabs deform due to temperature contraction and drying shrinkage, and resulting restraint cracking can impact flatness. And, for elevated slabs, the tensioning of tendons and removal of shoring can result in deflections that can impact flatness testing results. Concrete contractors are only responsible for establishing specified flatness during the finishing operations.

While the  $F_f$  measured using the F-number system has specific test requirements outlined in ASTM E1155,<sup>2</sup> the manual straightedge method is not covered by an ASTM test standard. However, ACI 117-10(15) provides compliance requirements for this method in Table 4.8.6.1. For the “Flat” floor surface classification, 90% of the test samples are required to be within a maximum gap of 1/4 in. under a 10 ft straightedge, and 100% of the test samples are required to not exceed a maximum gap of 3/8 in. (10 mm) under a 10 ft straightedge. A sample is a single placement of the straightedge. ACI 117-10(15) also requires a minimum number of samples based on the area of the floor (Section 4.8.6.2.2), as well as samples to be evenly distributed over the test surface (not closer than 5 ft [1.5 m] apart per Section 4.8.6.2.6).

ACI 117-10(15), Section 4.8.6.3, permits a computerized simulation of a freestanding 10 ft straightedge as an alternative to the manual test procedure discussed above or established in contract documents. As stated in Commentary Section R4.8.6.3, this method requires that data be collected along lines in a manner similar to the description in ASTM E1155 or ASTM E1486.<sup>3</sup>

So, as the GC surveyed the two placements in your project well beyond the required 72-hour limit, the opportunity to verify compliance with the specified 1/4 in. in 10 ft was missed. There is no way to determine whether or not the specified flatness was achieved during finishing operations as

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# Concrete Q&A

the time limit was exceeded, the tendons were tensioned, and the shoring was partially removed. It is unclear whether the GC even measured flatness correctly.

Compliance with the  $\pm 3/4$  in. deviation from elevation, as specified in ACI 117-10(15), Section 4.4.1, is an entirely separate requirement. And this requirement must also be measured before removal of supporting shores, so the test results obtained on your project cannot be used to verify compliance with that requirement either.

If these floors were measured within the required time limits and before the removal of shoring, the remedy for noncompliance for the elevated slab would be the same as the one provided in Commentary Section R4.8.4 of ACI 117-10(15) for slabs-on-ground:

“The remedy for noncompliance with specified defined flatness tolerances should be included in specification language. For random traffic slabs-on-grade, the remedy can range from liquidated damages, to localized grinding, to application of a topping, to removal and replacement, depending on the purpose for which the slab is being installed. The remedy for defined traffic installations is generally grinding of high spots.”

It is rare that a remedy is included in the contract documents. It is advisable that a discussion be held regarding the remedy prior to concrete placement and finishing. Depending on the intended use of the floor, an example of an appropriate resolution for noncompliance has been to provide a warranty covering an appropriate amount of localized grinding in areas that impact the operation. It is often difficult to predict whether noncompliance will actually impact a

random traffic operation but, occasionally, local issues arise at some joints over the first 2 years of service. An extended warranty to provide grinding at these localized areas, if and when they develop, has been a successful remedy. Note that grinding will remove the troweled surface finish and potentially expose aggregate, so owners may choose to forego grinding and accept the as-constructed surface until grinding actually becomes necessary. Therefore, when accepted as a remedy for noncompliance, the amount of potential grinding provided in an extended warranty should consider the type of operation anticipated as well as the design details for the floor (that is, the anticipated amount of deformation due to drying shrinkage and/or deflection after tensioning tendons, removing shoring, and concrete drying, none of which the concrete contractor is responsible for).

## References

1. ACI Committee 117, “Specification for Tolerances for Concrete Construction and Materials (ACI 117-10) and Commentary (ACI 117R-10) (Reapproved 2015),” American Concrete Institute, Farmington Hills, MI, 76 pp.
2. ASTM E1155-23, “Standard Test Method for Determining  $F_r$  Floor Flatness and  $F_L$  Floor Levelness Numbers,” ASTM International, West Conshohocken, PA, 2023, 8 pp.
3. ASTM E1486-14(2022), “Standard Test Method for Determining Floor Tolerances Using Waviness, Wheel Path and Levelness Criteria (Metric),” ASTM International, West Conshohocken, PA, 2014, 12 pp.

Thanks to Scott Tarr, North S.Tarr Concrete Consulting, PC, Dover, NH, USA, for providing the answer to this question.

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