

This article is a continuation of the "What's This Report For?" series, based on a technical session sponsored by ACI Committee E702, Designing Concrete Structures. In keeping with ACI's mission to provide knowledge and information for the best use of concrete, the articles will be posted on the ACI Web site (www.concrete.org/education/edu_online_CEU.htm) and, along with sample reports and multiple-choice questions, be used for educational materials.

The Floor Flatness Report

What the designer needs to know

BY MARK A. CHEEK

Floor profile finish quality has traditionally been specified by limiting the gap under either an unleveled or leveled 10 ft (3 m) straightedge. Some specifications still take this tolerance approach, even though there is no nationally accepted standard either for taking measurements or for establishing compliance of a floor profile. In many specifications, slab finish quality is not addressed at all. Use of a nonstandard test procedure and failure to specify floor profiles often lead to conflict and litigation. For example, if the project specification calls for a 10 ft (3 m) straightedge to determine the quality of the finished floor and the test area is 100 x 100 ft (30 x 30 m), a technician can place the 10 ft (3 m) straightedge at a single location and measure the gaps between it and the floor. Operating without a standard, the technician could simply use the measurement from that one location as representative of the entire test area. It may (by some chance) be representative of the whole floor but most likely is not; thus, the results obtained are essentially useless.

PROFILING STANDARD

The technology for measuring floor profiles has developed in response to the need for a standard method to evaluate them. This technology, called the F-number

system,¹ provides a welcome alternative and a solution to the generally recognized inadequacies of the 10 ft (3 m) straightedge to describe and define floor profiles.

Floor flatness (F_F) and levelness (F_L) numbers determine whether a floor is sufficiently smooth and level, respectively, as constructed. Floor flatness can affect flooring installation, ride quality and safety in warehouses, and drainage. Floor levelness can affect shelf placement and design and a slab's drainage plan. For example, the levelness of the floor in a warehouse could limit how high pallets of goods can be safely stacked. Typical F_F and F_L values for different applications are shown in Table 1 and Fig. 1.

Appropriate flatness and levelness

As in any other specification, the engineer should determine what is good enough for the application rather than impose a standard that is unnecessarily exacting and costly. Both overall flatness and levelness numbers should be specified, along with the local minimum values (typically 60% of the overall numbers). The test should be conducted within 72 hours of finishing the slab, as the curing process could cause the slab to curl and deviate from the flatness achieved by the finishers. Obtaining these numbers within 72 hours also allows the contractor

to make adjustments to the procedures, if necessary, while the floor is still being placed. Both flatness and levelness numbers can be determined on shored decks, but only flatness numbers can be determined on unshored decks.

Measurement

The F_F number is an indication of how bumpy or wavy the slab surface is, demonstrating the quality of the initial strike off and finishing process. The F -number system uses floor surface curvature calculated from elevation differences over 24 in. (600 mm) increments as a measure of flatness (Fig. 2). The F_L number is an indication of how level the slab is, demonstrating how level the forms were set. The floor slope is measured over a distance of 10 ft (30 m) (Fig. 3).

TABLE 1:
TYPICAL FLATNESS (F_F) AND LEVELNESS (F_L) NUMBERS FOR VARIOUS APPLICATIONS (ACI 302.1R)²

Composite flatness, F_F	Composite levelness, F_L	Typical applications
20	15	Noncritical: mechanical rooms, nonpublic areas, surfaces to have thick-set tile, parking structure slabs
25	20	Carpeted areas of commercial office buildings or lightly-trafficked office/industrial buildings
35	25	Thin-set flooring or warehouse floor with moderate or heavy traffic
45	35	Warehouse with air-pallet use, ice, or roller rinks
>50	>50	Movie or television studios

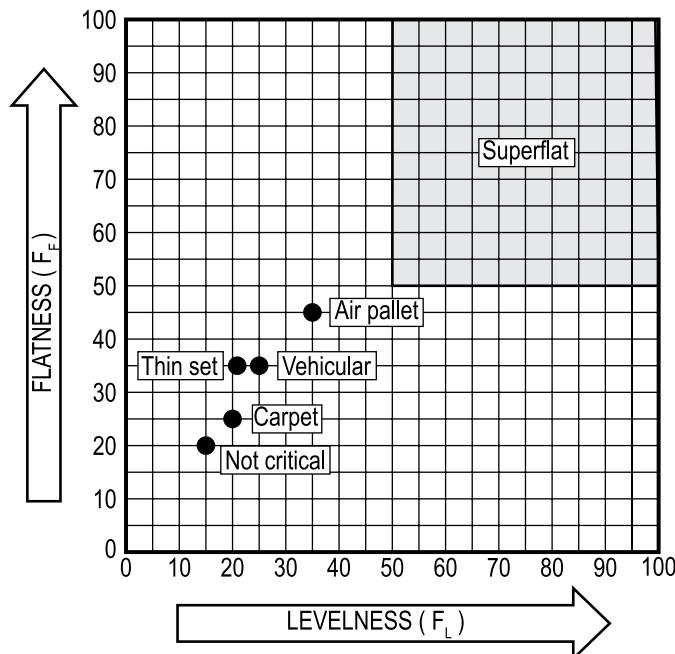


Fig. 1: Typical flatness and levelness requirements for various applications²

ASTM E1155, "Standard Test Method for Determining F_F Floor Flatness and F_L Floor Levelness Numbers," is a quantitative method of measuring floor surface profiles to obtain estimates of the floor's characteristic F_F and F_L numbers. Each slab requires a number of individual sample measurement lines (test runs). The quantity of test runs is determined by the area to be tested. The greater the area, the more test runs are required; thus, more data are accumulated and processed to determine F -number values for the slab.

In accordance with ASTM E1155, the test area must be organized into a test surface, test section(s), and test runs (Fig. 4). After the number and length of test runs are determined, the test runs can be laid out and the run path swept clean. Once the test runs are laid out and

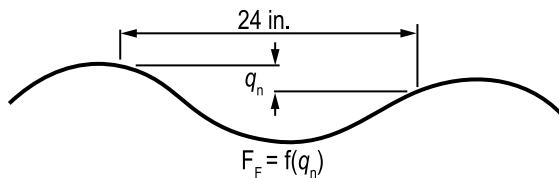


Fig. 2: The flatness is calculated from elevation readings over 24 in. (600 mm) increments

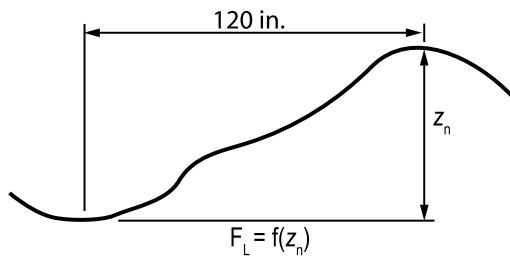


Fig. 3: The floor levelness is calculated from elevation readings over 10 ft (3 m) increments

cleaned, data can be collect using a Dipstick® floor profiler (Fig. 5) or equivalent. Minimum sampling requirements are discussed in ACI 117.²

Reviewing the report

A typical report includes a description of the test surface, test section(s) and location of test runs, the overall F_F and F_L numbers for the slab, the individual F_F and F_L numbers for each test run, and whether any required local minimum was violated. A graph of each test run may be included. The graph (Fig. 6) shows the change in elevation versus distance for the surface.

When reviewing a report, you should first verify that the overall F_F and F_L values meet the specified requirements. For example, suppose your project specification calls for a minimum F_F of 25 and a minimum F_L of 20. The corresponding minimum local values are typically 60% of these values, or 15.0 and 12.0, respectively; these should be spelled out in the specification. Looking at the example data in Table 2, you can see that the overall flatness and levelness requirements have been met.

After checking the overall flatness and levelness values against the specification, check the values of F_F and F_L for

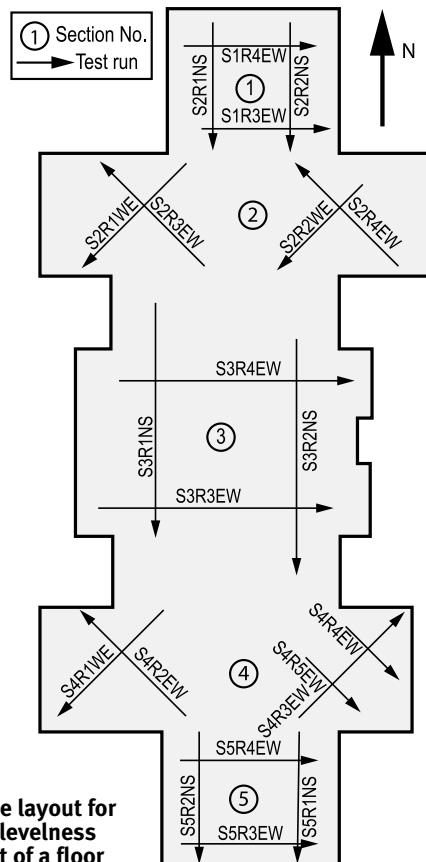


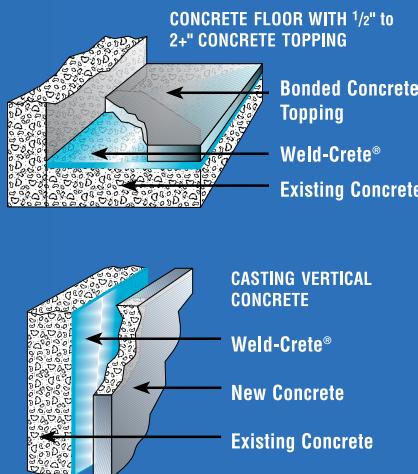
Fig. 4: Sample layout for flatness and levelness measurement of a floor

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the individual test runs. Figure 6 shows an example test run. The vertical scale is exaggerated to show the profile more clearly. In this case, $F_F = 26.71$, higher than the overall requirement and higher than the required local minimum of 15.0, and $F_L = 19.42$, lower than the overall requirement but higher than the required local minimum of 12.0.



Fig. 5: A Dipstick floor profiler is used to collect flatness and levelness data

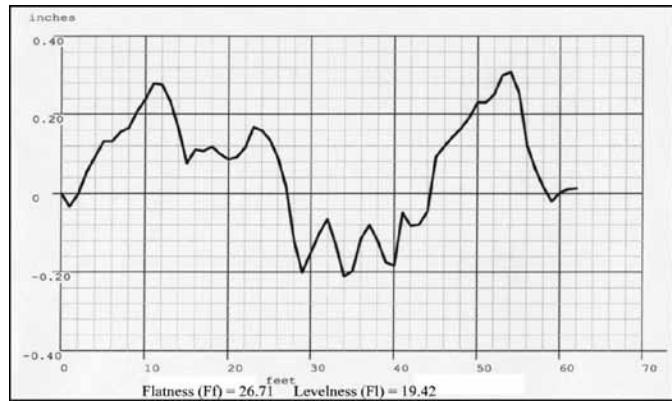


Fig. 6: Profile for one test run (vertical scale is exaggerated)

TABLE 2:
EXAMPLE FLATNESS AND LEVELNESS DATA FOR AN OFFICE BUILDING

Test run	Flatness, F_F	Levelness, F_L
1WE	35.13	24.70
2EW	24.71	11.42*
3WE	44.75	25.96
4NS	39.75	31.92
5SN	39.63	28.39
6NS	26.71	19.42
Overall (25/20)	35.11	23.80

*Does not meet the local minimum value

The last step is to check to see whether any local minimum values have been violated. Reviewing the data in Table 2, you can see that Test Run 2EW violates the minimum local value of F_L because it is only 11.42, less than the minimum local value 12.0. All other test runs meet the minimum local values for both F_F and F_L .

REMEDIES

If the overall F_F and F_L values exceed the minimum specified requirements and the minimum local values have not been violated, there is no need for remediation. However, if—as in the example—the overall values meet the specification and the minimum local values don't, the surface will need remediation in the areas where the minimum local values were out of spec. Additional testing will be required to determine the entire area for remediation. If the specified minimum overall numbers are not met, the entire surface or selected areas should be remediated and the surface retested. Remediation methods vary greatly in surface preparation, application effort, and cost so the selected remediation method varies from project to project.

Some reports may include measurements of the entire slab to quantify a slab that has been found to be out of spec. Different modeling programs can be used to aid in selecting a remediation method. For example, a mesh diagram (Fig. 7) can be very helpful in evaluating a slab surface.

If the results do not meet the specifications, remedial measures may be needed and a reduction in payment as previously agreed upon may be called for. Remedial measures for slabs-on-ground might include grinding, planing, surface repair, retopping, or removal and replacement. For suspended slabs, remedial measures are generally limited to grinding or use of an underlayment or topping material. Contract documents should clearly spell out the penalties to be imposed should the specified tolerances be exceeded. Generally, they will not mandate the remedial measures to be taken, as the Engineer of Record needs to make judgments about the appropriate action(s) in each individual case. In an office that is to be carpeted, a floor leveling compound may provide a sufficiently level surface for the carpet; for a warehouse floor, grinding the high spots may be preferred.

References

- Face, A., "Floor Flatness and Levelness—The F Number System," *Construction Specifier*, V. 40, No. 4, Apr. 1987, pp. 24-32.
- ACI Committee 302, "Guide for Concrete Floor and Slab Construction (ACI 302.1R-04)," American Concrete Institute, Farmington Hills, MI, 2004, 76 pp.
- ACI Committee 117, "Specifications for Tolerances for Concrete Construction and Materials and Commentary (ACI 117-10)," American Concrete Institute, Farmington Hills, MI, 2010, 76 pp.

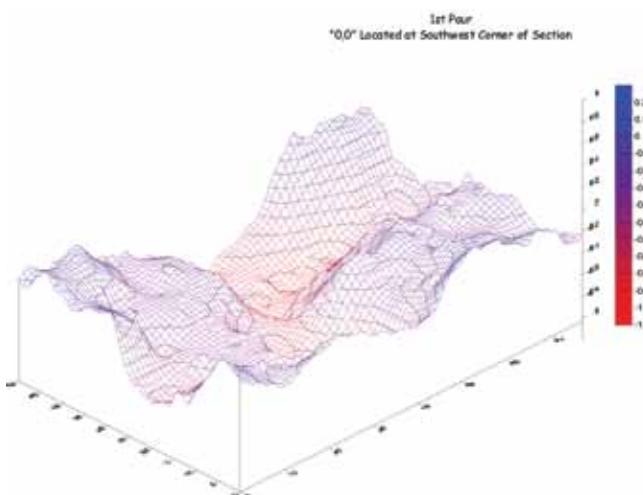


Fig. 7: Mesh diagram showing the profile of the surface. This type of diagram is useful in determining the appropriate repair method

Note: Additional information on the ASTM standard discussed in this article can be found at www.astm.org.

Selected for reader interest by the editors.



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