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 un leveled 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) straight edge 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, 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 (FF) and levelness (FL) 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 FF and FL 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)$^2$

<table>
<thead>
<tr>
<th>Composite flatness, $F_f$</th>
<th>Composite levelness, $F_l$</th>
<th>Typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>15</td>
<td>Noncritical: mechanical rooms, nonpublic areas, surfaces to have thick-set tile, parking structure slabs</td>
</tr>
<tr>
<td>25</td>
<td>20</td>
<td>Carpeted areas of commercial office buildings or lightly-trafficked office/industrial buildings</td>
</tr>
<tr>
<td>35</td>
<td>25</td>
<td>Thin-set flooring or warehouse floor with moderate or heavy traffic</td>
</tr>
<tr>
<td>45</td>
<td>35</td>
<td>Warehouse with air-pallet use, ice, or roller rinks</td>
</tr>
<tr>
<td>&gt;50</td>
<td>&gt;50</td>
<td>Movie or television studios</td>
</tr>
</tbody>
</table>

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
cleaned, data can be collected 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
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.

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**

Mark A. Cheek, FACI, is Vice President of Beta Testing & Inspection, LLC, New Orleans, LA. He has over 20 years of experience in construction materials testing and inspection. He is a Past President of the ACI Louisiana Chapter, and is a member of the Chapter Activities Committee, Certification Programs Committee, Convention Committee, and ACI Committees C610, Field Technician Certification; C620, Laboratory Technician Certification; 228, Nondestructive Testing of Concrete; 214, Evaluation of Results of Tests Used to Determine the Strength of Concrete; and E702, Designing Concrete Structures. He is also a member of Honors and Awards Committee and Chair of the ACI Young Member Award for Professional Achievement. Cheek received his BS in civil engineering from the University of New Orleans and is a licensed professional engineer in Louisiana and Mississippi.

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

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