



# Floor Flatness ( $F_F$ ) and Floor Levelness ( $F_L$ )



Concrete contractors will bid and pour floors to a specified American Concrete Institute (ACI) floor flatness ( $F_F$ ) requirement under Division 3 of the project specification(s). Tile and stone installation contractors bid and install the specified finish in accord with in plane surface tolerances under Division 9 of the project specifications. Even if the concrete contractor pours the concrete and finishes it to the specified floor flatness requirement, as stated in ACI 117 “Specification for Tolerances for Concrete Construction and Materials”, the  $F_F$  must be measured within 72 hours of the concrete pour. However, it is commonly known that concrete will continue to undergo change (e.g. shrinkage, curling, creep, etc...) over time. This means that even if the concrete slab meets  $F_F$  requirements within 3 days after the pour, by the time the tile contractor shows up on the site, more often than not, additional surface preparation is required. Design professionals must consider the effects of  $F_F$  change and how that change affects the ability of the flooring contractor to effectively install the specified finish to meet the expectations of the design professionals. The design professionals should specify a higher  $F_F$  rating and/or include an allowance for surface preparation in the specifications.

The proper preparation of substrates to receive most any type of finish flooring is critical to the aesthetic and functional performance of the floor. The substrate must meet certain requirements, again depending upon the finish material, for floor flatness and floor levelness. Installation of vinyl tile over a substrate which is not perfectly flat will be visible through the vinyl tile. Installation of tile or stone over a floor which is not flat can create low spots, lippage (a safety concern) and uneven grout joints. Installation of carpet over a floor which is not flat creates easily visible low spots. For tile or stone applications, the maximum allowable variation in the substrate, for tiles with edges shorter than 15” (380mm), is ¼” in 10’ (6mm in 3m) from the required plane with no more than 1/16” variation in 12” (1.5mm in 300mm) from the high points in the surface. For tile or stone with at least one edge longer than 15” (380mm) in length, maximum allowable variation is 1/8” in 10’ (3mm in 3m) from the required plane with no more than 1/16” in 24” (1.5mm in 600mm) when measured from the high points in the surface.<sup>1</sup>

Installation of certain types of finishes (e.g. tile, stone, vinyl tile, carpet) require surface preparation to ensure that certain floor flatness and floor levelness requirements are met. There are two standards for determining floor flatness and one for determining floor levelness. These standards are as follows;

1. **ACI 117 “Specification for Tolerances for Concrete Construction and Materials”** - This specification provides standard tolerances for concrete construction and is intended to be used as the reference document for establishing tolerances for concrete construction by specification writers and ACI committees writing standards. The 2010 revision of ACI 117 greatly expanded the straightedge method for determining floor flatness (Note that levelness cannot be determined using a straightedge).

ACI 117 sets minimum sampling requirements to help ensure a statistically representative set of measurements which is that one sample must be taken from each 100 ft<sup>2</sup> (9.3 m<sup>2</sup>), and samples must be taken parallel, perpendicular, or at a 45° angle to the longest construction joint of the test area.

The following chart shows the maximum gap between the floor surface and the bottom of the 10’ (3 m) straightedge. It is important to note that 90% of the samples must not exceed Column 2 and 100% of the samples must not exceed column 3.

Floor Surface Classification	Maximum Gap	
	90% Compliance	100% Compliance
Conventional	1/2" (12mm)	3/4" (19mm)
Moderately Flat	3/8" (10mm)	5/8" (16mm)
Flat	1/4" (6mm)	3/8" (10mm)
Very Flat	N/A	N/A
Super Flat	N/A	N/A

**Table 1 – Floor Flatness Tolerance Compliance**

The familiar 1/8" in 10' (3mm in 3 m) tolerance is not an option with ACI 117, which may present some difficulties for specifying slab tolerances for certain types of floor coverings. Consult the finish flooring manufacturer's instructions for acceptable substrate flatness tolerances.

2. **ASTM E1155 “Standard Test Method for Determining  $F_F$  Floor Flatness and  $F_L$  Floor Levelness Numbers”** – ASTM E1155 addresses a quantitative method of measuring floor surface profiles to obtain estimates of the floor's characteristic  $F_F$  Floor Flatness and  $F_L$  Floor Levelness Profile Numbers (F-Numbers). This standard establishes the method for measuring F-Numbers by using a statistical analysis of measured points which are 12" (300mm) apart taken along straight lines in a prescribed pattern within each sample area. A sample area must exceed 320 ft<sup>2</sup> (29.6 m<sup>2</sup>), must be at least 8' (2.4 m) wide, and must not cross a construction joint.<sup>2</sup>

ASTM E1155 provides statistical information concerning floor surface profiles and the results of this test method are used primarily to establish compliance of randomly trafficked floor surfaces with specified  $F_F$  Floor Flatness and  $F_L$  Floor Levelness tolerances, evaluate the effect of different construction methods on resulting floor surface flatness and levelness, and investigate the curling and deflection of floor surfaces.<sup>3</sup>

These F-Numbers use dimensionless symbols to designate both flatness and levelness and are designated as;

$F_F$  Floor Flatness – variation from surface plane (bumpiness)

$F_L$  Floor Levelness – variation from horizontal plane (pitch)

To specify F-Numbers correctly, two values are required for flatness and levelness:

- Specified Overall (SO  $F_F$  and SO  $F_L$ ) – these are the numbers as specified in the construction documents.
- Minimum Local (ML  $F_F$  and ML  $F_L$ ) – these are the minimum tolerances for the floor or slab to be usable (usually 60% of the Specified Overall value). Defects which exceed the Minimum Local value normally require some type of remediation (typically grinding, or, the use of a self-leveling underlayment).

F-Numbers must be measured within 72 hours of placing the slab because it ensures that the quality of the concrete contractor's quality is being measured. If the measurements are delayed, shrinkage, curling and other factors which are outside of the concrete contractor's control can influence the results. Levelness tolerances apply only to slab-on-grade and suspended slabs which are shored when tested.<sup>4</sup>

Floor Surface Classification	SO $F_F$	SO $F_L$
Conventional	20	15
Moderately Flat	25	20
Flat	35	25
Very Flat	45	35
Super Flat	60	40

**Table 2 – F-Number Method Reference Chart**

Conventional floors are not suitable for applied finishes and are normally used for utility spaces and left exposed. Moderately flat floors are suitable for carpeted finishes in commercial buildings and low speed vehicular traffic in industrial buildings. Flat floors are suitable for tile, vinyl tile and similar finishes as well as for conventional fork lift traffic in warehouses. Very flat floors are usually used for high-end industrial applications where high speed fork lifts and

other production equipment are used. Super flat floors are appropriate for very limited applications with random traffic such as television studios to minimize camera vibration.

The information on tile size and grout joint width, provided below in Tables 3 & 4, is not exact. The information is provided to show general guidelines on how to reconcile subfloor requirements contained in Division 3 and Division 9 of typical project specifications.

Tile Size* (+/- 1/2" [12mm])	Grout Joint Width	Grout Joint Width	Grout Joint Width
	1/4" (6mm) or wider	3/16" (5mm)	1/8" (3mm)
8" x 8" (200 x 200mm)	F <sub>35</sub> or 1/4" in 10'	F <sub>45</sub> or 3/16" in 10'	F <sub>60</sub> or 1/8" in 10'
12" x 12" (300 x 300mm)	F <sub>35</sub> or 1/4" in 10'	F <sub>45</sub> or 3/16" in 10'	F <sub>60</sub> or 1/8" in 10'
16" x 16" (400 x 400mm)	F <sub>35</sub> or 1/4" in 10'	F <sub>45</sub> or 3/16" in 10'	F <sub>60</sub> or 1/8" in 10'
18" x 18" (500 x 500mm)	F <sub>45</sub> or 3/16" in 10'	F <sub>60</sub> or 1/8" in 10'	F <sub>60</sub> or 1/8" in 10'
24" x 24" (600 x 600mm)	F <sub>45</sub> or 3/16" in 10'	F <sub>60</sub> or 1/8" in 10'	F <sub>60</sub> or 1/8" in 10'
36" x 36" (900 x 900mm)	F <sub>50</sub> or 1/8" in 10'	F <sub>60</sub> or 1/8" in 10'	F <sub>60</sub> or 1/8" in 10'

\* For non-square units, the tile size shall use the information based on longest side dimension (see Table 4)

**Table 3 – Grout Joint Size Relative to Subfloor Flatness Minimum Requirements – Minimum subfloor flatness using ASTM E1155 FF (SOF<sub>F</sub>) or a 10' (3m) straightedge**

Longest Side Tile Dimension	Grout Joint Width	Grout Joint Width	Grout Joint Width
	1/4" (6mm) or wider	3/16" (5mm)	1/8" (3mm)
Up to 16" (400mm)	F <sub>35</sub> or 1/4" in 10'	F <sub>45</sub> or 3/16" in 10'	F <sub>60</sub> or 1/8" in 10'
>16" to <36" (400 to 900mm)	F <sub>45</sub> or 3/16" in 10'	F <sub>60</sub> or 1/8" in 10'	F <sub>60</sub> or 1/8" in 10'
36" or over	F <sub>60</sub> or 1/8" in 10'	F <sub>60</sub> or 1/8" in 10'	F <sub>60</sub> or 1/8" in 10'

**Table 4 – Non-Square Tile Unit Grout Joint Size Relative to Subfloor Flatness Minimum Requirements - - Minimum subfloor flatness using ASTM E1155 FF (SOF<sub>F</sub>) or a 10' (3m) straightedge**

To make sure that a floor meets the standards needed for a particular type of flooring finish, a family of products (self-leveling underlayments) has been developed. Self-leveling underlayments are essentially a very fluid, pourable mortar which, like any fluid material, seeks its own level. LATICRETE and DRYTEK offer self-leveling products (e.g. NXT™ Level Plus, DRYTEK LEVELEX Plus, and more) which are ideal for use under ceramic tile, stone, vinyl tile, sheet vinyl, hardwood, laminate flooring, carpet, and glass tile. DRYTEK also offers a cementitious topping material (DRYTEK LEVELEX DL) which is used as the finished surface and can be colored and polished to achieve a myriad of design options. Consult the finish flooring manufacturer's instructions for acceptable substrate flatness tolerances.

<sup>1</sup> TCNA Handbook for Ceramic, Glass and Stone Tile Installation 51<sup>st</sup> Edition, Tile Council of North America, Anderson, SC, 2014.

<sup>2</sup> Stutzman, David. Floor Slab Flatness & Levelness, Conspectus, Inc., [www.conspectus.com](http://www.conspectus.com)

<sup>3</sup> ASTM E1155 Standard Test Method for Determining F<sub>F</sub> Floor Flatness and F<sub>L</sub> Floor Levelness Numbers, American Standard for Testing and Materials, Conshohocken, PA, 2008.

<sup>4</sup> Stutzman, David. Floor Slab Flatness & Levelness, Conspectus, Inc., [www.conspectus.com](http://www.conspectus.com)

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