Correlation Between Division 3 Floor Flatness (F_F) and Floor Levelness (F_L) and Division 9 Substrate Tolerances

TDS 233

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, typically, 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 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.[1]

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^2 (9.3 m^2), 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' (3m) 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^2 (29.6 m^2), must be at least 8' (2.4 m) wide, and must not cross a construction joint.[2]

   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.[3]

   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.[4]

Floor Surface Classification	SOF_F	SOF_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* (+/- ½" [12mm])	Grout Joint Width	Grout Joint Width	Grout Joint Width
	¼" (6mm) or wider	3/16" (5mm)	1/8" (3mm)
8" x 8" (200 x 200mm)	F_{35} or ¼" in 10'	F_{45} or 3/16" in 10'	F_{60} or 1/8" in 10'
12" x 12" (300 x 300mm)	F_{35} or ¼" in 10'	F_{45} or 3/16" in 10'	F_{60} or 1/8" in 10'
16" x 16" (400 x 400mm)	F_{35} or ¼" in 10'	F_{45} or 3/16" in 10'	F_{60} or 1/8" in 10'
18" x 18" (500 x 500mm)	F_{45} or 3/16" in 10'	F_{60} or 1/8" in 10'	F_{60} or 1/8" in 10'
24" x 24" (600 x 600mm)	F_{45} or 3/16" in 10'	F_{60} or 1/8" in 10'	F_{60} or 1/8" in 10'
36" x 36" (900 x 900mm)	F_{50} or 1/8" in 10'	F_{60} or 1/8" in 10'	F_{60} 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_F) or a 10' (3m) straightedge

Longest Side Tile Dimension	Grout Joint Width	Grout Joint Width	Grout Joint Width
	¼" (6mm) or wider	3/16" (5mm)	1/8" (3mm)
Up to 16" (400mm)	F_{35} or ¼" in 10'	F_{45} or 3/16" in 10'	F_{60} or 1/8" in 10'
>16" to <36" (400 to 900mm)	F_{45} or 3/16" in 10'	F_{60} or 1/8" in 10'	F_{60} or 1/8" in 10'
36" or over	F_{60} or 1/8" in 10'	F_{60} or 1/8" in 10'	F_{60} 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_F) or a 10' (3m) straightedge

To make sure that a floor meets the standards needed for a certain flooring type, 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 LATICRETE® SUPERCAP® offer self-leveling products (e.g. NXT® Level Plus, SUPERCAP SC500, and more) which are ideal for use under ceramic tile, stone, vinyl tile, sheet vinyl, hardwood, laminate flooring, carpet, and glass tile. LATICRETE also offers three cementitious topping material (NXT Level DL, NXT Level SP and LATICRETE SUPERCAP SC650-MC) which can be 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.

[1] TCNA Handbook for Ceramic, Glass and Stone Tile Installation (2019), Tile Council of North America, Anderson, SC, 2019.

[2] Stutzman, David. Floor Slab Flatness & Levelness, Conspectus, Inc., www.conspectus.com

[3] ASTM E1155 Standard Test Method for Determining F_F Floor Flatness and F_L Floor Levelness Numbers, American Standard for Testing and Materials, Conshohocken, PA.

[4] Stutzman, David. Floor Slab Flatness & Levelness, Conspectus, Inc., www.conspectus.com

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