PDHonline Course S130 (1 PDH)

Concrete Slab Finishes and the Use of F-number System

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Background:

Starting in the 1970's, ACI targeted the conventional 1/8" in 10'-0" floor finish, or "straightedge spec", as an area that needed more uniform and realistic methods of specification and monitoring. This need was felt because of the ambiguous nature of the traditional straightedge specification. For example 1/8" in 10'-0" could mean either of the two conditions shown in Figure 1 below.

In addition, the straightedge method had no standard test method; therefore field conditions were often subject to interpretation. For example does the spec 1/8" in 10'-0" mean that measurements are taken at points both 360° and 90° from each other? Are measurements cumulative along lengths greater than 10'-0"? Finally, the straightedge specs do not address floor flatness (roughness or wash boarding) or levelness (tilt or slope).

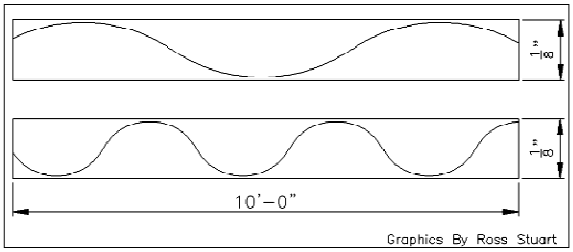


FIGURE 1

What are F-Numbers?

The F-Number system is a statistical method of evaluating horizontal concrete surfaces for flatness and levelness. The Face Company, in conjunction with ACI Committee 117, developed the basis for the system through the use of a patented continuous Profileograph machine. For a typical random traffic industrial or other similar floor slab there are two F-Numbers used to evaluate the floor flatness and levelness, F_F and F_L; respectively. F_F (flatness) is most affected by the finishing operation. F_L (levelness) is most affected by forming and strike-off. Both numbers are dimensionless and the higher the number the more accurate the floor construction.

The F_F number relates to the rate of change of the elevation of a concrete floor over a 12" interval. The rate of change of slope is represented by the value q. A hump in a slab produces a negative q value while a trough or depression produces a positive q. F_F is calculated using the following formula:

$$F_F = 4.57 / ((3 \times Sq) + (| q |))$$

Where: Sq = the standard deviation of q

| q | = the absolute value of the mean of q

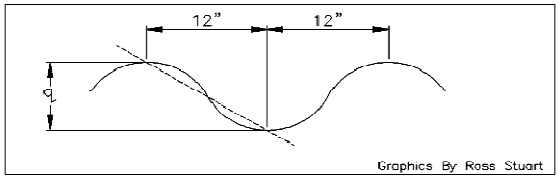


FIGURE 2

The F_L number relates to the general floor slope of a concrete slab from an assumed datum elevation. The difference in elevation of two points which are 10'-0" apart are measured as the value z. F_L is calculated using the following formula:

$$F_L = 12.5 / ((3 \times Sz) + (| z |))$$

Where: Sz = the standard deviation of z

| z | = the absolute value of the mean of z

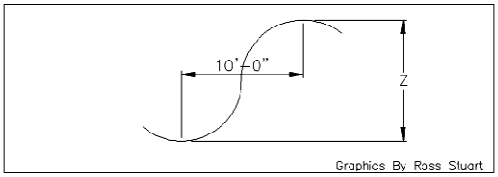
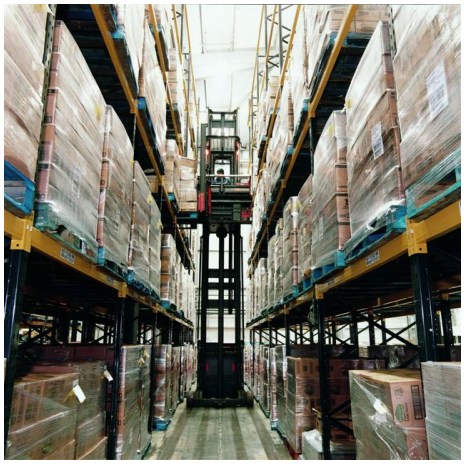


FIGURE 3

For defined traffic industrial floor slabs, such as very-narrow-aisle warehouses where forklifts travel the same path, an F_{min} numerical system is used. F_{min} is not calculated like F_F or F_L. F_{min} is actually a direct measurement of the floor surface in the wheel path of the forklift for which the defined traffic area is designed. An $F_{min}100$ specification is a baseline number corresponding to a flatness tolerance of 1/8" in 10'-0". An $F_{min}50$ specification corresponds to a flatness tolerance of 1/8" in 5'-0", or 1/4" in 10'-0".



Source: T2 Storage Solutions

How are F-Numbers Specified?

ACI 117 is the industry standard for the use of the F-Number system and establishes the F-Numbers of different types of floors as well as the definitions of acceptable variances. ACI 302 also provides guidelines for the placing and finishing of concrete floor slab construction for the F-Number system. ASTM E 1155 is the basis of the standard test method for the F_F and F_L number system. One of the most important aspects of establishing F-Numbers is to not over specify beyond that which is really required for a given project. This is because an increase in required floor quality will almost always result in higher costs. One of the best methods for determining the most appropriate criteria to specify for a project is to measure existing floors that are performing satisfactorily. Specifications should state the performance criteria only and not specify the method of obtaining the required tolerances. This is recommended because the quality of work varies from finishing crew to finishing crew for any given standard technique used in the field.

Source: Warehouse & Logistics News

F_F and F_L are typically specified for both overall and minimum local values. This helps prevent the acceptance of isolated local areas of low quality construction due to it being averaged in with other areas of the slab that surpass the minimum requirements. The specified overall values describe the flatness and levelness values that must be achieved when all measured values on a given test surface are combined. The minimum local values describe the flatness and levelness values below which repair or replacement is required within the affected area. The general rule of thumb is that the local area minimum must be within 2/3 of the specified overall value. On elevated slabs the F_L levelness tolerance does not apply because of the deflection of the overall framing system and should therefore not be specified. Only F_F numbers should be specified for elevated slabs.

YOU THINK ALL FLOORS ARE FLAT?

TTL news

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f-numbers - concrete floor slab flatness and levelness

WHAT ARE F-NUMBERS?

F-Numbers determined in accordance with ASTM E 1155 are the generally accepted measurements for evaluating flatness and levelness of concrete slabs. The F-Number system was adopted by ACI Committee 117 to replace the traditional "1/8-inch in 10-feet" or straightedge specification for floor finishes. The straightedge specification is generally unreliable, immeasurable, and unrealistic for controlling a floor profile. The following table gives an approximate comparison of F-Numbers to the outdated straightedge specification. The ACI 302 "Guide for Concrete Floor and Slab Construction" provides detailed guidance on selection of appropriate F-Numbers based on planned usage. The report covers typical F-Numbers for varying classes of floor slabs along with typical finishing techniques used to achieve these finishes.

Approximate Equivalent FF Value and Straightedge Measurement	
Floor Flatness (FF)	Deflection Under 10' Straightedge
25	1/4"
50	1/8"
100	1/16"

F-numbers quantify floor flatness and levelness:

• *Floor flatness (FF) relates to the bumpiness of the floor. Flatness measurements are most affected by the finishing operation. Flatness relates to the rate of change in the elevation of the floor over a 12-inch section.*

• *Floor levelness (FL) relates to the slope or tilt of the slab across the section evaluated. Levelness is most affected by forming operations and strike off of the concrete during placement. Levelness measures the difference in elevation between two points which are 10-feet apart.*

F-Number values are dimensionless and higher values indicate flatter or more level floors. F-Numbers are linear measurements so a FF value of 40 is twice as flat as a FF value of 20.

HOW ARE F-NUMBERS SPECIFIED?

Specified F-Number tolerances should include a Specified Overall Value (SOV) and a Minimum Local Value (MLV) for a project. The SOV refers to the average specified F-Numbers for all the floor slabs on the project. The MLV refers to the minimum acceptable F-Numbers for any individual floor slab section. The MLV is typically lower than the SOV to allow contractors a margin of error to correct for variations in construction methods on any one floor slab placement.

Larger floor slabs are typically placed in sections over several different placement dates. For each slab placement (test section), F-Numbers should be measured and compared to the project MLV. The results from each test section are averaged to determine if the means and methods being used by contractors are resulting in F-Numbers which meet the project SOV.

An example of a typical specified tolerance for a Random Traffic Floor is:

Floor Flatness (FF):	Specified Overall Value	= 35
	Minimum Local Value	= 24
Floor Levelness (FL):	Specified Overall Value	= 25
	Minimum Local Value	= 18

The American Concrete Institute requires that specified concrete floor tolerances be checked within 72 hours after floor installation in order to ensure that an accurate gauge of the surface's "as-built" shape is assessed. Typically, F-Numbers are measured as soon as finishing is complete and the placement will tolerate foot traffic. Project specifications for floor tolerances should specify the required corrective measures for the overall slab or individual slab placements that do not meet the project requirements. Remedial measures could include repair by re-topping, removing and replacing sections, or monetary rebates to the owner for out-of-tolerance work. Grinding of deficient areas is typically not a preferred solution because of the difficulty in improving the F-Numbers and the reduced surface durability and appearance.

HOW ARE F-NUMBERS MEASURED?

F-Number measurements should be performed in general accordance with ASTM E-1155 "Standard Test Method for Determining Floor Flatness (FF) and Floor Levelness (FL) Numbers". Several different techniques are allowed for measuring the F-Numbers of Random Traffic Floors, but the most commonly used equipment (and the equipment used by TTL) is the dipstick floor profiler.

F-Numbers are normally measured soon after the final finishing (troweling) of a concrete slab section. Measurement lines are commonly laid out across the slab (to provide an equal number of readings in the longitudinal and transverse directions) and readings are taken at 1-foot intervals on the line. Measurement lines must be a minimum of 11 feet long and a minimum of 34 readings should be taken for each 1,000 square feet of floor area. Measurements are taken with the dipstick by walking the apparatus along the line and measuring the difference in elevation between points 12 inches apart along the length of the line. The more modern dipstick profiler machines record the readings each time the apparatus is pivoted and the alternating foot is placed on the slab. F-Number results are generally available immediately after completion of the measurements in the field.

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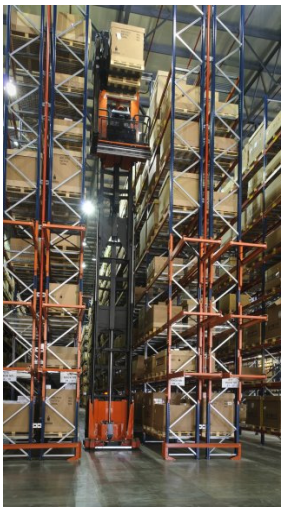
Source: TTL Inc.

Lift and forktruck manufactures publish recommended F_{min} floor tolerances to assure the proper operation of their equipment. The higher the number the flatter and more level the floor requirement is. $F_{min}100$ is typically referred to as a "Superflat" floor requirement. Producing an $F_{min}100$ tolerance in any direction on a floor is comparable to producing a floor surface meeting F_F140 and F_L100 tolerances.



Source: Creamer Media

An additional ASTM specification, E 1486 can be used to determine the deviation from a 10-foot straightedge for both random and defined traffic floors in order to determine the "Waviness Index". In addition this specification provides defined wheel track equations for specifying elevation differences and change in elevation transversely between left and right wheel tracks and longitudinally from front to rear axle , therefore this spec can be used as a standard for evaluating F_{min} floor tolerances.

Source: Dynamic Floor Specialists

The following table can be used as a guideline for specifying F-Numbers for various floor profile categories:

Recommended F-Numbers for Various Floor Profile Categories					
Floor Profile Category	Random Traffic Floors				Defined Traffic Floors
	Specified Overall Value		Minimum Local Value		
	F_F	F_L	F_F	F_L	F_{min}
Conventional (using bullfloat)	19	13	13	10	19
Conventional (using highway straightedge)	25	17	13	10	25
Good	38	25	19	13	38
Flat	50	33	25	17	50
Very Flat	75	50	38	25	75
Superflat	100	66	50	33	100
Ultraflat	150	100	75	50	150

In addition, although there is no direct equivalence between F-Numbers and traditional straightedge specifications the following table provides an approximate correlation between straightedge measurements and F_F Numbers.

Approximate Equivalence of F_F Numbers and Straightedge Measurements	
F-Number	Gap Under 10'-0" Straightedge
12	1/2"
20	5/16"
25	1/4"
32	3/16"
50	1/8"

How are F-Numbers Measured?

Floor flatness and levelness tests should be conducted anywhere from within 16 to 72 hours after completion of the final troweling operation, depending on the project type and requirements. As it is typically not practical to obtain acceptable local values across construction joints it is recommended that these areas be omitted from consideration for comparison to the specified minimum local value. It should also be noted that it is entirely possible that the floor can be within specified tolerances during the initial testing process but become out of spec prior to actual use because of slab cracking, curling or sub-grade settlement.

ASTM E1155 is the governing specification for the testing procedures used to determine floor flatness and levelness for random traffic floors. This standard allows for numerous techniques for gathering the required date including levels, inclinometers, Profilometers and other means. One of the most often used pieces of equipment for these measurements is the Dipstick floor profiler, an apparatus that can field measure both floor flatness and levelness. This equipment can be programmed to measure floor slabs on slopes also.

Source: Concrete Bindings LTD

For defined traffic floors such as rack aisleways where the wheel traffic occurs in the same location for all operations, instead of random sampling, traffic paths are directly measured using a continuous recording floor Profilometer configured to run in exactly the same specified wheel tracks as the forktrucks. The results of the measurements taken do not produce F-Numbers, but instead simply confirm compliance with the minimum requirements specified. Changes in elevation and rate of change are confirmed in both the longitudinal and transverse direction of the wheel travel. The record of measurements indicates the exact location of any areas that are not in compliance.

Source: CoGri Korea Company

Concrete Slab Finishing Specification Example:

The following is an example of a performance-based specification for concrete finishing as it relates to the F-Number system. **Red** text that is located within brackets indicates alternate or optional items depending on the nature of the project:

A. Concrete Finish: Concrete finish floors shall have a [**hard steel troweled finish; light broom finish**] unless indicated otherwise on the drawings. Place, strike off, consolidate, level and float to the proper elevation. Troweling shall begin after surface has received a float finish. The slab drying must proceed naturally and must not be hastened by the dusting on of dry cement or sand. Lightly tool all edges at construction joints and exercise care that slab edges are not depressed along bulkheads during finishing operations, particularly hand troweling. Exterior slabs, sidewalks, pads and ramps shall have a light broom finish unless indicated otherwise on the drawings. Provide standard trowel finish at all sub-slabs.

1. Random traffic floors shall conform to the following surface profile tolerances:
   a. Floor Designation: All floor areas not specified to be part of the "defined traffic floor" should be part of the "random traffic floor". Any floor slab comprising part of the random traffic floor shall be designated a "random traffic slab".
   b. Flatness and Levelness Tolerances: The random traffic floor shall conform to the following surface profile tolerances:
      Floor Flatness Number: F_F
      Specified Overall Value = [**35**]
      Minimum Local Value = [**24**]
      Floor Levelness Number: F_L
      Specified Overall Value = [**25**]
      Minimum Local Value = [**18**]
   c. Floor Tolerance Measurements: F_F and F_L tolerances shall be tested in accordance with ASTM E 1155. Actual overall F-numbers shall be calculated using the inferior / superior area method.
   d. Timeliness of Floor Profile Tests & Reports: All floor tolerance measurements shall be made within [**48**] hours after slab installation. In all cases, tolerance measurements shall precede the removal of shores and forms. Results of all floor profile tests (including a running tabulation of the overall F_F and F_L values for all of the random traffic slabs installed to date) shall be provided to the Contractor within [**72**] hours after each slab installation.
   e. Remedy for Out-of-Tolerance Work: For the purposes of flatness and levelness control, minimum floor section boundaries shall coincide with the control joints. Profile test compliance requirements apply to that time period specified above only. The Contractor shall remedy any floor section measuring below either the minimum local F_F number, or F_L number. Any floor section measuring at or above both the minimum local F_F number and the minimum local F_L number shall be accepted. If the actual overall F_F number or the actual overall F_L number for the entire random-traffic floor installation measures less than its specified value, then the Contractor shall undertake the remedial measures that have been approved by the Engineer.
2. Defined traffic floors shall conform to the following surface profile tolerances:
   a. Floor Designation: All floor areas specified as "defined traffic floor" include only the [**rack aisleways**].
   b. Flatness and Levelness Tolerances: The defined traffic floor shall conform to the following surface profile tolerances: F_{min} = [**75**]
   c. Floor Tolerance Measurements: F_{min} tolerances shall be tested in accordance with ASTM E 1486.
   d. Timeliness of Floor Profile Tests & Reports: All floor tolerance measurements shall be made by the contractor within [**24**] hours after slab installation and before saw cutting of control joints. In all cases, tolerance measurements shall precede the removal of shores and forms. Results of all floor profile tests including a running tabulation of the overall F_{min} values for all of the defined-traffic slabs installed to date shall be provided to the Contractor within [**48**] hours after each slab installation.
   e. Remedy for Out-of-Tolerance Work: For the purposes of flatness and levelness control, minimum floor section boundaries shall coincide with the construction joints. Profile test compliance requirements apply to that time period specified above only. The Contractor shall remedy any floor section measuring below the F_{min} number, in accordance with the recommendations of the Engineer. Any floor section measuring at or above the Fmin number shall be accepted. If the actual overall F_{min} number for the entire defined-traffic floor installation measures less than its specified value, then the Contractor shall undertake the remedial measures that have been approved by the Engineer.
3. If a portion of a floor does not meet the specified F-number the following remedies are recommended:
   a. Local value is out of spec - grind or replace floor.
   b. Overall value is out of spec - the contractor shall pay the owner per square foot for portion of floor not meeting F-number spec. This can be done by specifying a figure in the project specifications in conjunction with the square footage obtained from reading taken in the field.