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INDUSTRIAL FLOORING TECHNOLOGY SERIES- #2 FLATNESS

Ok, so what is flat? What is flat enough? How do you know if it is? Can you prove it? These are all good questions and ones being asked more and more often. When we first got into the Industrial Flooring Business concrete flatness was not even mentioned. Over time it became more important especially when the high stack pallet racks became popular and the concrete floor had to be VERY flat and regular for the forktrucks to lift loads up to the 4th and 5th rack level without swaying and perhaps falling over.

The FACE Company devised a quantative way to both define and measure floor flatness allowing this aspect of concrete flat work to have a definite and unequivocal specificity. To save time I have included an excellent write up taken from the FACE Company web site defining just what their measures do measure. Ff is floor flatness and Fl is how level – or not- the floor is. Together they very well define the surface.

Ok, so what does this have to do with industrial flooring? Well a LOT. Very roughly one might consider an Ff of <20 to be a very irregular, lumpy, bumpy, and, a very poorly finished floor surface. It usually means something went out of control and very wrong in the finishing process. In many industrial situations this would bring about removal and replacement of the concrete. Ff of 20-30 is a marginal, very obviously bumpy and a poorly finished floor. Ff 30-50 might be considered an "average" industrial floor placed without laser screeds and perhaps typical of work done 20 years ago. Today Ff of 50+ is common with some contactors routinely doing Ff70+ work. One is even telling of 300,000 sqft all done with an Ff+70 finish. WOW nice work! An Ff of 100+ is considered a "super flat", requiring exceptional attention and craftsmanship to achieve, and will be priced accordingly.

So what about the floor coating guys? For the most part, simply put, we are a contour following craft. If we get a great flat concrete surface, we produce a great looking surface, and we really should give some of the credit to the concrete guys here. If we get a low F number surface our work highlights the irregularities.

A common question is, "Well can you grind a bit to fix the imperfections?", .. not at all an unreasonable question. The problem is that "correcting" the imperfections while using a thin film coating – say up to 30 or so mils is roughly equivalent to auto body work on a giant scale. You cannot do just a little and make it look good. Whatever you don't do is still obvious and looks bad. Again yelling at the floor coating guy may give some satisfaction, but provides little in the way of a satisfactory remedy.

Here are pictures of Lyle Marier grinding patching and smoothing a badly damaged 1000 sqft photographic "sweep" floor at Apple Studios.

The requirement was to get a smoothness (flatness) such that a Kleg light at ankle height in a dark room wouldn't cast a shadow. I estimated that this would be an Ff of 200+ or so. It took 2+ weeks of work with successive grinding and patching to achieve this, just in time for an Easter photographic shoot with their major customer. This is a $30-$50/sqft repair today.

Recently we were asked to estimate what it would take to repair a 26000 sqft of a supposedly Ff20 floor. To get it to maybe an Ff40 or so we thought perhaps $200,000 and 4 – 6 weeks of work. There is no technology to simply dump some "self leveling epoxy" on the floor and magically make it good. (Self leveling epoxy levels out flat on a flat floor.) VERY specialized laser guided grinding is necessary if this technique is to be used, not many contractors can do this and is quite expensive.

This is even worse if you want a silicate sealed or silicates sealed and polished floor. There is nothing to patch and the shiny surface ABSOLUTELY shows all the irregularities. Polishing will likely scalp the highs and show the stone in the concrete while the lows remain with some cream still there. The silicate makes the concrete impossible to coat so you are stuck with a poor looking job.

The net result is what the concrete guys give us GREATLY determines what the end result will be. If the guys ahead of us do good work we all look like heroes, but if they don't, we all have a LOT of excuses to make.

I hope this helps
Tom Hennessy ChE

FACE® **The World Leader in Precision Profiling**

The 40 Most Asked Questions about F-Numbers

1. What are F-Numbers?

The F-Number System is **the American Concrete Institute** (ACI 117) and **Canadian Standards Association** (CSA A23.1) standard for the specification and measurement of concrete floor flatness and levelness. F-Numbers replace the familiar "1/8th inch in ten feet" type specs that had proven unreliable, unmeasureable and unrealistic.

The new standards include **two F-Number**s:

F_F for **flatness** and F_L for **levelness**

Flatness relates to the bumpiness of the floor, while levelness describes the local tilt or pitch of the slab. The higher the F-Number, the better that characteristic of the floor. F-Numbers are linear, so an F_F 20 is twice as flat as an F_F 10, but only half as flat as an FF 40.

Slabs-on-grade are usually specified with an F_F number and an F_L number (the **F_F is always listed first**), such as :

F_F 25 / F_L20

Because of deflection, **elevated slabs are usually specified using only F_F.**

When a floor is described as an "F 25", it usually means "F_F 25".

The **ACI/CSA F-Number System** applies to 99% of all floor slabs - all floors that support **random traffic**, be it vehicular or pedestrian traffic.

In the tiny percentage of floors that have **defined traffic**, where vehicles are restricted in their movement by wire or rail guidance, **a different F-Number - Fmin** - is used. This System is used in conjunction with consultation services provided by The Face Companies.

Most **Superflat** floors should use the F_{min} System, since most of these slabs support **defined traffic**.

2. What was wrong with the old "straightedge" specs?

There was disagreement as to what they meant.
Did "1/8th inch in ten feet" mean ± 1/8" in 10' (a horizontal 1/4" envelope which is 10' long) - or - did it mean ± 1/16" in 10' (a horizontal 1/8th inch envelope which is ten feet long)?

Straightedge measurements were unscientific and non-repeatable.
Before F-Numbers, floors were only "measured" long after the fact, when someone didn't like the floors' general appearance. That's when the straightedge was finally hauled out by the aggrieved party in an effort to prove his case. Of course, no two people got the same results, since there was no standard for either the test method or for interpreting the results.

They were unrealistic.
Although "1/8th inch in ten feet" has been used to specify billions of square feet of concrete, it was seldom, if ever, achieved. The typical industrial floor, for example, is closer to a horizontal 5/8th inch by ten foot envelope.

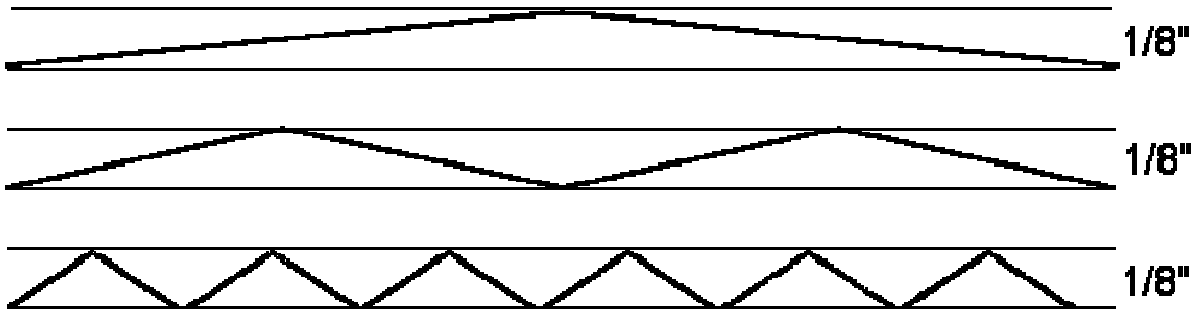
3. If floor measurements are so inaccurate, how can you determine floor flatness at all?

During the last 25 years, **extremely accurate floor measuring instruments have been developed.**
One, **the Profileograph, produces continuous measurements of wheeltrack areas** along designated vehicular travel paths. The Profileograph is used only on Defined Traffic Floors.

Another instrument, the **Dipstick Floor Profiler**, produces a point-to-point graph of the surface measured, as well as the data required to compute ACI/CSA F-Numbers for **Random Traffic Floors**.

4. Now that you can make accurate measurements, why can't we keep using the straightedge specs?

Straightedge specifications didn't control the characteristics of the floor that relate to its usefulness.
For instance, all of these floor profiles would satisfy the "1/8th inch in ten feet spec":



Since all these floor profiles would meet the 1/8th" spec, **the straightedge specs themselves simply were not capable of controlling the floor profile.**

5. How are F-Numbers better?

F-Numbers control both the floor's "envelope" and its bumpiness.
Or, if you **think of the floor profile as a wave, F-Numbers control both the wave's amplitude and its frequency**.
F-Numbers have shown the ability to identify and to control floor characteristics which are critical to the floor's usefulness.

6. What F-Number equals 1/8th" in 10'?

For all of the reasons outlined already, there is no F-Number equivalent to any straightedge spec. But, rough equivalents, in terms of horizontal envelopes, can be given:

An FF 25 is roughly equivalent to a single ± 1/4" defect in 10'
An FF 50 is roughly equivalent to a single ± 1/8" defect in 10'
An FF 100 is roughly equivalent to a single ± 1/16" defect in 10'

7. Since I've been meeting 1/8th" in 10 ' for years, why should I have any problem meeting an FF 50 ?

Because you weren't meeting 1/8th inch in 10 feet! Just because the floor was accepted and paid for doesn't mean it was actually that flat. *The only time you can be sure you actually built a floor to a specific tolerance is if the floor was measured.*
In all probability, most of the concrete floors placed in the last 50 years would measure somewhere between F_F 15 and F_F 35; that's something like horizontal envelopes measuring 1 inch by 10 feet - to 3/8ths inch by 10 feet.

8. How can I find out what F-Numbers I have been producing ?

Just hire a testing lab to measure some of your old jobs. If your local test lab doesn't have a Dipstick, you can rent or purchase one and measure the floors yourself. Then, you will know exactly what F-Numbers you have been able to produce under the particular circumstances of each project you measured.

9. I don't need floors that are very flat, so why should I worry about F-Numbers?

Using F-Numbers doesn't mean that floors have to be specified flatter than is needed. But, without F-Numbers, there is no way to measure reliably what floor flatness/levelness was actually produced.
The average industrial floor is about an F_F 20-25 / F_L 15-20. Many building owners are satisfied with this result, but some would find areas of the floor that they would want "fixed".
What happens if the floor profile is not specified at all, and an F_F 12 / F_L 8 is produced? Most owners are not going to be happy with this result.
But without clearly defining what is and is not satisfactory in the floor specification, the developer of the building has no control whatsoever over what he is buying.

10. What good does it do to measure a floor after it's already in place ... isn't it already too late?

F-Numbers were not invented as a way to find somebody to blame. Properly used, F-Numbers identify problems and help prevent their recurrence.
After gaining experience with F-Numbers, a contractor can select placement and finishing procedures which will make a failure very unlikely.
F-Number measurements should be taken as soon as each day's placement will bear foot traffic. In most cases, the F-Numbers for that slab can be determined within an hour or two and a report generated before the next slab is placed.
With daily measurement, a construction problem can be identified and corrected before it's repeated.

11. That's great for the second placement, but what do you do to make sure the first pour is okay?

Placing floors to achieve certain F-Numbers is not guesswork.

Millions and millions of square feet of concrete have been placed using the F- Number System. Concrete contractors have learned that, by using certain placement and finishing techniques, they can routinely achieve different F-Numbers (see Measuring the Quality of Floor Finishes).

Therefore, if a job is specified F_F 25 / F_L20, a contractor should use procedures which typically produce those F- Numbers or, to play it safe, methods which produce marginally higher F-Numbers.

So, the keys to meeting F-Numbers specs are:

1. **Choose the correct placement and finishing procedures to meet the specified F- Numbers.**
2. **Measure each day's work as soon as possible so, if there's a problem, it will be identified before it's repeated.**

12. How does a novice know what F-Numbers to specify?

There are two ways to select the proper F-Numbers for a given floor usage.

The first *and the best* way is to identify a floor in a building that the user is already happy with. The F-Numbers for this floor can then be measured and used to develop a new floor specification.

If that's not practical, you can use F-Numbers suggested by the American Concrete Institute and others, which are based on hundreds of projects around the country.

13. How are F-Numbers measured?

F-Numbers are derived from a statistical analysis of the floor's elevation measured at one-foot intervals. The elevation differences over two feet are used to determine F_F , while the differences over ten feet are used to determine F_L. Basically, measurement lines are laid out on the floor, and elevation measurements are taken every one foot down the line. Each measurement line should be at least 11 feet long, and at least 34 individual elevation measurements should be taken for each 1,000 square feet of floor area. Detailed rules for performing F-Number tests are set forth in ASTM E-1155. After collection, the elevation readings are put into standard mathematical formulae to calculate the floor's F-Numbers. Several devices are approved by ASTM for F-Number measurement, including the Dipstick Floor Profiler.

14. How long does it take to measure a floor?

A single operator with a Dipstick can collect enough readings **in 60 to 90 minutes** to measure the typical day's slab-on-grade placement. With the Dipstick® 2000, 2200, or 2272, the data can then be analyzed right on the Dipstick®. Alternatively, the data may be downloaded to a PC at your office for analysis later.

15. What if the floor doesn't meet the specified F-Numbers?

This is a question that must be answered <u>before the construction of the floor begins</u>. The "what-if's" should always be addressed in the floor specification. Each floor should be specified using two pairs of F-Numbers called:

Specified Overall F-Numbers and
Minimum Local F-Numbers.

The **Specified Overall F-Numbers** represent the minimum values allowed for the entire floor, looked at as a whole. The **Minimum Local F-Numbers** define the minimum quality acceptable to the Owner - the lowest results allowed in any one floor section. These numbers are generally set at about 2/3 of the **Specified Overall Numbers**. This allows contractors sufficient margin for the normal variations that occur with a given construction method. *However, no floor should be spec'ed with Minimum Local values lower than F_F 13 / F_L 10; this is the worst result to be tolerated from any construction technique.*

The idea is that if the Contractor aims above the **Overall F-Numbers**, he will, at least, average those Overall values - and it is very unlikely that he will fail to achieve the **Minimum Local F-Numbers**.

16. That makes the odds better, but say the Contractor does miss the Minimum Local F-Numbers?

As we've pointed out, the **Minimum Local F-Numbers** give the Contractor very considerable room for error, but if he does miss even these lower numbers, he has only two choices:

1) Repair (this almost always means re-topping) all defective sections.
2) Remove and replace all defective sections.

But don't worry too much about ripping out slabs right and left. **If the proper procedures are used, the chances of failing to meet Minimum Local F- Numbers on a project are almost zero.**

17. What about localized grinding as a repair?

Because F-Numbers are a statistical measurement, localized grinding usually doesn't work on Random Traffic Floors. If the grinding removes what looks like a "bump" in one direction, the grinding might be creating a "dip" when the floor is measured in another direction.

Unless there is a very obvious local defect, **grinding is not a solution.**

18. What happens if the Specified Overall F-Numbers are missed?

Because the specification has already defined the **Minimum Local F-Numbers** as "acceptable", no corrections are mandated by failing to satisfy the **Specified Overall F-Numbers.** But clearly, **the floor produced was not the floor specified. The Face Companies' recommended solution is a rebate formula.** The floor specification should include a per-square-foot figure for the number of square feet that does not meet the **Specified Overall F-Numbers.**

19. How can you figure out how much of the floor fails to meet the Specified Overall F-Numbers?

The software which comes with every model of the Dipstick automatically calculates the floor area equal to spec, the floor area better than spec, and the floor area worse than the spec.

20. Does this mean I have to buy a Dipstick to put in a floor specified with F-Numbers?

The Dipstick offers the fastest, easiest and most economical way to monitor F-Number projects, but, in most cases, purchase of a Dipstick in order to measure a single project is neither necessary nor advisable.

Many testing labs already have Dipsticks and offer F-Number measurement as part of their overall quality control services. Dipsticks are also available for rent - by the week or the month.

21. Can anyone operate a Dipstick?

People who have never run a Dipstick should receive one or two days of training in the operation of the instrument and in F-Number measurement procedures.

This training and Dipstick certification are offered by The Face Companies.

Official ACI, CSA and ASTM documents should always be kept available for quick reference on jobsite.

22. Is it okay if F-Number measurements are taken less frequently - maybe even just at the end of the job?

The ACI mandates F-Number measurement within 72 hours of slab installation (this would allow a Friday pour to be measured on Monday). On most projects, daily testing is best.

A significant delay between placement and measurement can allow shrinkage or deflection phenomena (such as curling) to affect the results. One of the objectives of timely measurement is to establish clearly whether the Contractor did or did not

do his job, so that the cause and remedy of any problems found can be easily determined.

23. How can I improve the F-Numbers I get?

There are many factors which influence F-Number results, but there is a simple way to look at it:

F_F = finishing F_L = forming & strike-off

The quickest, easiest and **least expensive way to improve flatness (F_F)** is to replace the bullfloat with a highway straightedge. At no extra cost, this simple equipment substitution alone can result in an increase of 25% to 50% in the resulting FF numbers.

By increasing the number of highway straightedging operations during the finishing process (after floating, refloating, etc.), higher and higher F_F numbers can be achieved. The distance between edge forms may have to be reduced below 25 feet to achieve F_F numbers above 40.

The accuracy in setting forms and the accuracy of the strike-off operation have the greatest impact on levelness (F_L). Because of the increased number and intensity of operations, more labor is generally required to achieve higher and higher F-Numbers.

24. Why is flatness important on elevated slabs?

While its cosmetic importance is obvious, slab flatness/levelness also has a major impact on the ease, efficiency and cost of finishing out tenant spaces. The construction and installation of door frames, movable partitions, pre-fabricated cabinetry and elevator landings are impacted by the flatness and levelness of the floor slabs.

25. How do F-Numbers work on elevated slabs?

In most cases, only the F_F number is specified on elevated slabs. That's because elevated slabs deflect - and **the contractor can't totally control how much deflection occurs.** ***The use of F_L on elevated slabs is limited to specific situations*** where the floor profile is analyzed when :

a) the slab is still supported in its original as-cast position; and
b) the slab has no camber.

26. What FF Numbers should be specified for elevated slabs?

An Overall F_F 25 is well received by most Owners and can be achieved without significant cost burden. The Face Companies recommend that **no elevated slab should be specified lower than Overall F_F 20**. The right F_F for each job will depend on the use of the floor. For instance, a floor that will be tiled should be flatter than a floor that will be carpeted.

27. Even though F_L shouldn't be used on most elevated slabs because of deflection, isn't controlling deflection still important?

Yes. Although F-Numbers aren't the answer for controlling deflection, the Dipstick can be used to produce floor profiles before and after shore removal. By studying the amount of deflection which occurs, design and construction procedures can be modified until optimum results are achieved.

28. Without an F-Number for deflection, how is it specified and controlled?

The Face Companies recommend that the elevated slab **specification require that a certain percentage of the elevation points** measured using ASTM procedures *after deflection has occurred* **fall within a defined envelope**.

Based on Face Companies research, most **Owners are happy** with the result if **80% of the sample falls within a 3/4 inch envelope.**
During measurement and data analysis, each measurement line is tied to a design elevation to make this analysis possible.

29. How long does it take to measure an elevated slab?

In order to perform the deflection analysis unique to elevated slabs, extra care is taken to identify each measurement line before readings are taken.
This means that elevated slabs take a little more time to measure.
Generally, 20,000 to 25,000 sq. ft. of elevated slabs can be measured in two to two and a half hours.

30. How are defects in elevated slabs repaired?

The most common repair method is patching (or "skim-coating"). Floor locations identified by Dipstick survey as needing repair may be as small as an area bounded by column lines and half-column lines.
Suspect areas identified by the initial ASTM E 1155 measurement are usually re-measured in more detail to establish the boundaries of the repair.

31. What is a Superflat Floor?

By definition, **Superflat = F_{min} 100**

The word *Superflat* was first used by The Face Companies in the 1970's to describe the flatness/levelness required to support full-speed, trouble-free operation of Very Narrow Aisle (VNA) lift trucks.

Since F_{min} is the Defined Traffic F-Number, it cannot be measured using the *ACI/CSA/ASTM F-Number System*.

In order to achieve this high degree of flatness/levelness, Superflat floors must be placed in long, narrow strips. The forms for Superflat placements must be set with great precision. Specialized finishing techniques and continuous quality control measurement are also required. The services of a floor design/construction consultant are usually advisable.

For **Random Traffic Floors**, Superflat is often defined as **F_F 100/F_L 50**; but Superflat tolerances are rarely required on Random Traffic Floors and should be specified only in extraordinary circumstances.

32. How is a Defined Traffic Superflat Floor measured?

Floor consultants from The Face Companies measure F_{min} using the **Profileograph**, in conjunction with their overall design, construction and certification services.
For **Random Traffic Floors**, F-Numbers can be measured using the Dipstick Floor Profiler - but, again, the **Dipstick should never be used to measure narrow aisle warehouse floors or any Defined Traffic Floor.**

33. Isn't a Random Traffic Superflat Floor the same thing as a Defined Traffic Superflat Floor?

No. A **Defined Traffic Floor** (such as a narrow aisle warehouse) supports traffic which moves along the exact same tracks all the time.
This means that the travel paths can be measured using an instrument that precisely simulates the behavior of the vehicles which will be used on the floor. This kind of vehicle simulator (such as the Face Floor Profileograph) is configured to mimic the wheel pattern of the actual lift truck to be used. The instrument rolls down the vehicle travel paths and records the *relative* motion of its wheels, side to side and front to front.
With this kind of *continuous* simulation measurement, local defects (bumps or dips) in the tracks can be identified and

corrected by localized grinding.
In contrast, ACI/CSA/ASTM F-Numbers (Random Traffic F-Numbers) are not measured from a continuous profile. The one-foot measurements do not simulate what the lift truck "sees" and cannot, therefore, be used to identify and repair specific wheel track defects.

34. How much does a Superflat floor cost?

The cost of making a floor Superflat varies significantly from one region of the country to another. The premium on smaller projects (25,000 sq. ft. and under) is especially difficult to generalize.
But *on average*, turning a conventional floor into a Superflat floor (all other things being equal) will likely increase the floor's cost between $ 0.90 and $ 1.50 per square foot.
Most of the extra costs are related to the additional labor required for special forming and finishing procedures, and the reduced production rates achieved (4,000 to 6,000 sq.ft./day per crew on the average).

35. I can understand how grinding can be used to correct high spots on Superflat floors, but how can grinding fix low spots?

If there is a spot that is too low in a Superflat **Defined Traffic** wheelpath, grinding can be used to smooth out the dip lengthwise down the track - and to lower the elevation of the opposite wheeltrack to level the location.

36. Can a floor be Superflat even if it is designed to slope?

Yes. Design slope can be compensated for in Superflat measurements.

It's important to remember that the floor profile characteristics that are critical to efficient, full-speed vehicle operation are the flatness/levelness characteristics *under the wheels of the vehicle*.

In most cases, the truck really doesn't care if one end of the aisle is higher or lower than the other. It only cares how many bumps and dips it encounters in getting from one end to the other.

37. Can't I save money by making my floor Superflat only in the travel paths and not under the racks?

This is not a good idea in most cases.

Remember, Superflat floors are placed in long, narrow strips. The strips are arranged to conform to the racking layout for the warehouse. The long edges of each strip are positioned so they will end up in the middle of adjacent racking sections. The aisleway *and the travel path* are located down the middle of each strip.

Since forming the aisleway separately would require twice as much forming and twice as many slab placements, this approach is usually not practical - nor does it produce significantly better F-Numbers.

The floor specification should include a per-square-foot figure for the portion of the floor that does not meet the Overall F-Numbers.

38. Can a floor be built so it's Superflat in all directions Ñ so I could move my racks in the future without worrying about floor flatness?

No one has figured out a way to build a Superflat joint, so building a floor that's Superflat in all directions is not yet possible. Using the best installation technologies available, the practical limit in as-built omni-directional flatness/levelness is about F_F

39. How can I make an existing conventional floor Superflat?

There are two alternatives:

1) a Superflat topping; or
2) Superflat grinding.

Both options require specialized knowledge, both in planning and executing the repair.
The services of an floor consultant experienced in topping and grinding repairs should be retained early in the decision-making process.

40. How do I get more information on F-Numbers and floor flatness/levelness?

You can click the links below for information, or call the Face Companies at (757) 624-2121, or E-Mail us with your questions at dipstick@faceco.com

Gap Under Straightedge *216 KBytes*
Minimum Local F-Numbers *21 KBytes*
FF & FL *73 KBytes*
ASTM E-1155 *67 KBytes*
How to measure ASTM E-1155 *762 KBytes*
Dipstick Capabilities *14 KBytes*
Dipstick Hints & Layout *43 KBytes*
Elevation Studies *46 KBytes*
Sample Specs *102 KBytes*
Setting up a Test Track *59 KBytes*
Changes made to ASTM E-1155 in 1996 *6 KBytes*

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#12. All success is gained a little at a time.. sometimes you don't even notice it ..