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The 40 Most Asked Questions about F-Numbers

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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 replaced the older "1/8th inch in ten feet" type specs that had proven unreliable, unmeasurable and unrealistic.

There are two F-Numbers: FF for flatness, and FL 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 FF 20 is twice as flat as an FF 10, but only half as flat as an FF 40.

Slabs-on-grade are usually specified with an FF number and an FL number (the FF is always listed first), such as:
FF 25 / FL20

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

When a floor is described as an "F 25", it usually means "FF 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. The Fmin system is described in more detail below. Any slab that supports defined traffic, such as high-bay, narrow aisle warehouses, should be specified and measured in the Fmin system.

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 $\pm 1/8"$ in 10' (a horizontal 1/4" envelope which is 10' long) - or - did it mean $\pm 1/16"$ 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 typically 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 5/8th inch deep envelope, rather than a 1/8th inch deep envelope.

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

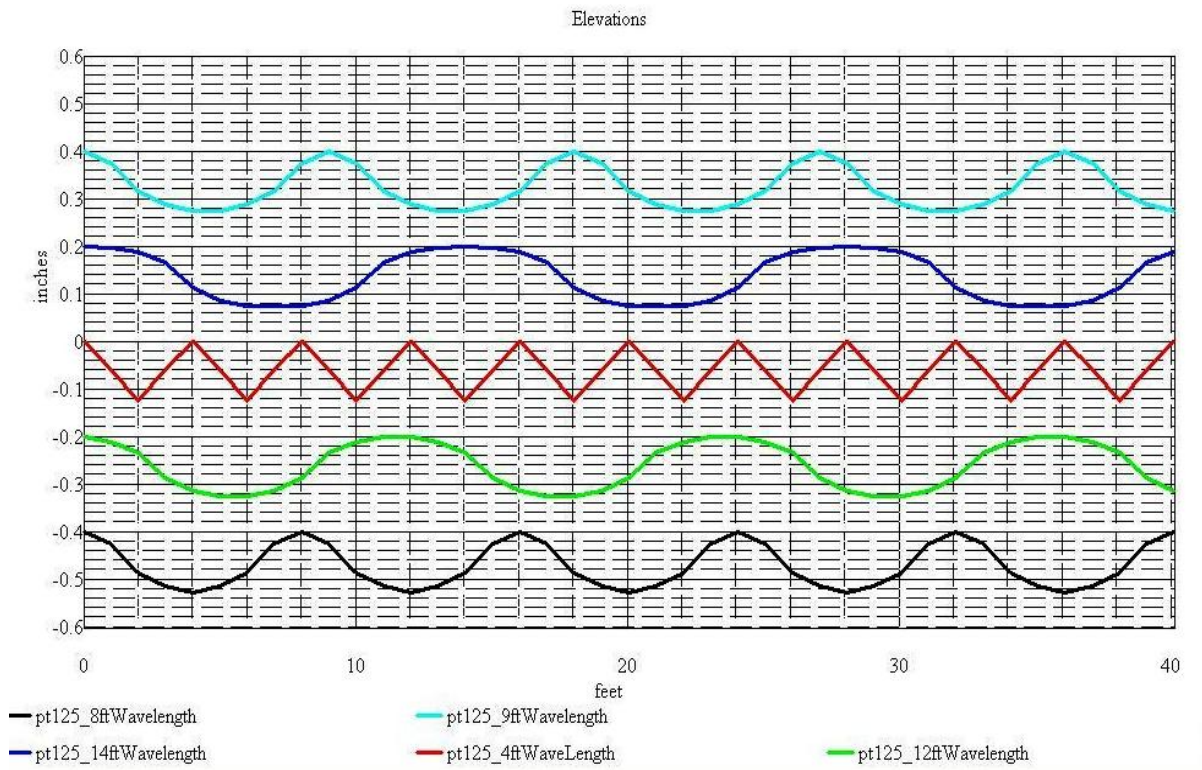
During the last 40 years, extremely accurate floor measuring instruments have been developed.

- The first such device was the Face[®] Profileograph, which produces continuous measurements along the wheeltracks of designated vehicular travel paths. The Profileograph was used only on Defined Traffic Floors (Fmin).
- 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. The latest versions of the Dipstick[®] include a broad range of surface profile analysis packages, including Fmin.

4. Now that we have precise and accurate instruments, why can't we just keep using the straightedge specs?

Straightedge specifications didn't control the characteristics of the floor that relate to its usefulness.

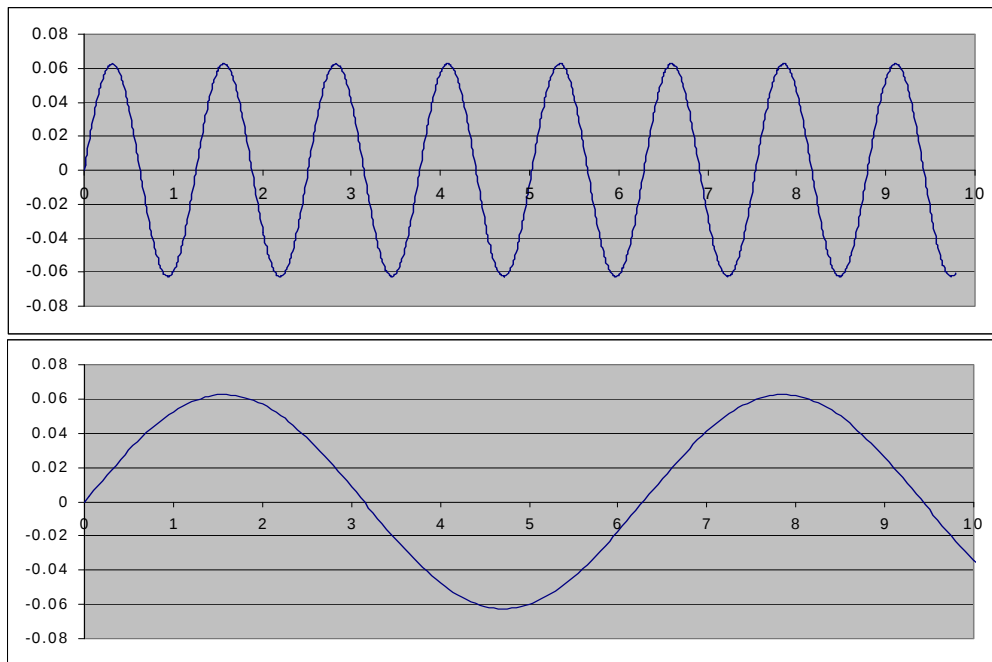
For instance, all of these floor profiles would satisfy the "1/8th inch in ten feet" spec:



Clearly, the usefulness of the floors shown above varies wildly. The F-Numbers range from FF 16 to FF 83. Since all these floor profiles would meet the "1/8th inch" spec, the straightedge specs themselves simply were not capable of distinguishing between good and bad floors.

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. The two profiles shown below both meet "1/8 in ten", but the flatness of these two floors is obviously different.



F-Numbers have shown the ability to identify and to control floor characteristics that are critical to the floor's usefulness.

6. What F-Number equals 1/8th inch 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 $\pm 1/4"$ defect in 10'
 An FF 50 is roughly equivalent to a single $\pm 1/8"$ defect in 10'
 An FF 100 is roughly equivalent to a single $\pm 1/16"$ defect in 10'

7. Since I've been meeting 1/8th inch 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 by a very accurate instrument. In all probability, most of the concrete floors placed between 1950 and 1990 would measure somewhere between FF 15 and FF 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 ?

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.

Before the revolution in finishing triggered by accurate profile measurement, the average industrial floor was about an FF 20-25 / FL 15-20. Many building owners were satisfied with this result, but some would find areas of the floor that they wanted "fixed."

But what would happen if the floor profile is not specified at all, and an FF 12 / FL 8 is produced? Most owners are not going to be happy at all 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.

By the way, 20+ years after F-Numbers were adopted by the ACI, the typical industrial floor is about 50% flatter and more level... without the owner paying any premium. That's because F-Numbers gave contractors and equipment manufacturers reliable data... so finishing procedures and equipment have greatly improved.

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 that 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 can be generated before the next slab is placed.

With daily measurement, a construction problem can be identified and corrected before it is 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.

Billions 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. ACI 302 lists the procedures that should be considered to achieve different F-Number values.

Therefore, if a job is specified FF 25 / FL20, 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:

- Choose the correct placement and finishing procedures to meet the specified F- Numbers.
- Measure and report each day's work as soon as possible so, if there's a problem, it will be identified and corrected before it is 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 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 thousands of projects around the country. They provide a small list of “typical use” floors with recommended standard F-Number specifications.

13. How are F-Numbers measured?

F-Numbers are derived from a statistical analysis of the floor's elevation measured at one-foot (300 mm) intervals.

To determine “Flatness”, we measure the change in slope over two feet (600 mm). Imagine a mirror propped up at a small angle on the floor. The slope of the face of the mirror does not change over the length of the mirror. If the slope does not change, the surface is said to be “flat”, even if it is not level. On a floor, many measurements of slope are collected and the results are treated statistically, resulting in an FF (Face Flatness) Number. If the average change in slope is small, the floor is said to be relatively flat. If the average change in slope is large, the floor is “bumpy” or not flat.

To measure “Levelness”, we measure elevation differences over ten feet (3m). On a floor, many measurements of 10-ft elevation differences are collected and the results are treated statistically, resulting in an FL (Face Levelness) Number. If the average elevation difference over 10 feet is small, the floor is said to be relatively level. If the average elevation difference over 10 feet is large, the floor is not level.

Measurement lines are laid out on the floor, and elevation measurements are taken every one foot down the line. Each measurement line must 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 E1155. After collection, the elevation readings are put into standard mathematical formulae to calculate the floor's F-Numbers.

Several devices are produced for F-Number measurement, including the Dipstick® Floor Profiler. Not all floor profilers are alike, so you should be sure to get one that is both accurate and precise enough to give repeatable, reliable F-number reports. Time after time, it has been shown that two or more Dipsticks, operated by different people, will produce the same result, while certain other devices produce different results every time they are used,

even on the same floor. If you get a different number every time you measure the floor, you can never be sure what the correct number is.

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

A single operator with a Dipstick® can collect enough readings in an hour to measure the typical day's slab-on-grade placement. The Dipstick 2272 produces graphs of each run and the F-Numbers for each line of data the instant you press <Enter> to stop collecting data. The instant you press <Escape> to close the graph, you'll see a report that gives the F-Numbers for the placement to date, including all the data that has been collected on this slab so far. You can also download the data in perhaps ten seconds to a laptop or PC at your office to print reports.

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

This is a question that must be answered before the construction of the floor begins. 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 required F-Numbers for the entire floor, looked at as a whole. The Minimum Local F-Numbers define the minimum quality acceptable to the building 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 specified with Minimum Local values lower than about 15, because 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 what if 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:

- Repair all defective sections, usually after the owner's rep approves the repair approach.
- 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 quite low.



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17. What about localized grinding as a repair?

Because F-Numbers are a statistical measurement, localized grinding usually doesn't work well 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, or unless a 3-D map is made of the floor surface, (the Dipstick can produce 3-D map data), grinding is not normally a good solution.

18. What happens if the contractor passes the Minimum Local F-Numbers but fails to achieve the Specified Overall F-Numbers?

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 specification, 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, most accurate and most economical way to monitor F-Number projects, but, in most cases, it is neither necessary nor advisable to purchase a Dipstick in order to measure a single project. 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?

Anyone who can read can operate a Dipstick. The operator's manual is very complete, with many photos, charts, and diagrams to help the novice. There is even an "1155 Helper[™]" manual inside the Dipstick Operator's manual, plus the Dipstick comes with "1155 Helper" software that makes it easy to lay out a slab for measurement.

Many companies would rather expedite the learning process and ensure that their people are fully trained in all aspects of floor measurement before they take on F-Number measuring jobs. For these people, The Face Company offers an intensive, two-day F-Number/Dipstick School. At the end of the second day of training, students take an exam. Those that pass are certified by The Face Companies to be able to measure floors properly.

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. Ideally, the test results should be made available to all parties within 24 hours whenever possible.

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. The other key objective of early measurement is to ensure that all parties are aware of the flatness and levelness of each slab of the floor surface as it is placed. In this way, if any corrective actions are needed, they can be made before more floor slabs are placed.

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

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

FF comes from the finishing tools and techniques used; FL results from the formwork & strike-off tools and techniques used.

The quickest, easiest and least expensive way to improve flatness (FF) is to replace the bullfloat with a highway straightedge or “bump cutter”. 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 FF numbers can be achieved.

The accuracy in setting forms and the accuracy of the strikeoff operation have the greatest impact on levelness (FL). It is quite difficult to get decent FL Numbers using the Wet Screed technique, simply because it is hard to get the wet pads at the exactly correct elevation. Screed rails are easier to get good FL Numbers with, and any kind of form-to-form strikeoff will produce very good FL Numbers if the forms are set carefully.

Because of the increased number and intensity of operations, more labor is generally required to achieve higher and higher F-Numbers. On larger projects, higher F-Numbers can also be achieved by using equipment such as the Somero Laser Screed[®]. Because a Somero Laser Screed controls strike-off elevations very well, using one makes it fairly easy to get relatively high FL Numbers; and because the strike-off head is 12 ft wide, the resulting FF Numbers are usually quite good too.

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 FF 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 FL on elevated slabs is limited to specific situations where the floor profile is analyzed when:

- the slab is still supported in its original as-cast position; and
- the slab has no camber, or
- the elevated slab has been produced in two stages, where the final lift is placed on an already-deflected deck.

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

An Overall FF 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 FF 20. The right FF 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 FL 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 E1155 measurement are usually remeasured in more detail to establish the boundaries of the area needing repair.

31. What is a Superflat Floor?

The Face Companies define Superflat as Fmin 100. The word Superflat was first coined by The Face Companies in the 1970s to describe the flatness/levelness required to support full-speed, trouble-free operation of Very Narrow Aisle (VNA) lift trucks.

Since Fmin is the Defined Traffic F-Number, it cannot be measured using the ACI/CSA/ASTM F-Number System, but it can be measured using the Dipstick.

In order to achieve this high degree of flatness/levelness, Superflat floors must usually 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 sometimes defined as FF 100/FL 50; ACI now refers to Random Traffic Floors measuring FF 60/FL 40 as "superflat". Superflat tolerances are rarely required on Random Traffic Floors and should be specified only for projects requiring extraordinary flatness and levelness, such as for television studios.

32. How is a Defined Traffic Superflat Floor measured?

The Dipstick[®] can now be used to measure narrow aisle warehouse floors or any Defined Traffic Floor. The directions are provided in the operator's manual, and the software is provided by the Face Company. You can now do your own measuring and reporting of Fmin Numbers. For Defined Traffic Floors, only the wheelpaths are measured. Before measuring, it is critical that the precise location of each future aisle be known. Additionally, the specific make and model of MHE must be specified, because different fork trucks have different wheelbases.

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 high-bay, narrow aisle warehouse) supports traffic which moves along the exact same tracks all the time. This means that the travel paths must be measured precisely in the wheelpath of the vehicle which will be used on the floor. The special measuring technique and the special software are used to simulate the behavior of the vehicles which will be used on the floor. The special "vehicle simulation" software simulates the motion of the fork truck as it rolls down the wheel paths and determines the relative motion of its wheels, side to side and front to back. With this kind of simulation analysis, local defects (bumps or dips) in the tracks can be identified and corrected by localized grinding.

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 match the elevations across the two wheeltracks.

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 placing my Superflat floor only in the travel paths and not under the racks?

This is not a good idea in most cases.

Remember, Superflat floors are typically 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.

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

While it is possible, using the best processes and procedures available today, to produce a floor with very high flatness and levelness in all directions, this approach is not practical in most cases. The cost of building a floor that is superflat where it needs to be - only in the wheelpaths of precisely defined aisles - is *far* less than the cost of building a floor that is superflat everywhere and superflat in all directions.

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

There are two alternatives:

- a Superflat topping; or
- Superflat grinding.

Both options require specialized knowledge, both in planning and executing the repair. The services of a 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 visit the Flat Floor Library™ at www.Dipstick.com, or call The Face Companies at (757) 624-2121, or toll-free in the USA and Canada at 1 (800) F-NUMBER (that's 1 (800) 368-6237) or E-Mail your questions to Dipstick@FaceCo.com.

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