



Subsurface Tolerances and Floor Flatness Requirements — A Case for Cementitious Self-Leveling Underlayments

It is common knowledge that putting more effort into surface preparation will yield benefits in your floor covering installation. Not only will the floor covering be easier to install but a truly flat floor will have an aesthetic quality that building occupants will appreciate. While there are many minimal industry standards for achieving a flat floor, the question remains: Do they go far enough? As the flooring industry continues to evolve — and architects and designers become more exacting — construction methods must continue to evolve.

Substrate flatness is best achieved through the application of a flowable and cementitious self-leveling underlayment.



Photo Courtesy ABW Construction – Woodinville, WA



Today there is a growing demand for larger format ceramic and natural stone tiles. This necessitates proper specification and execution of floor surface preparation, particularly in relation to floor flatness, which is critical to any successful floor covering installation. To insure a higher quality appearance and reduced life cycle cost, the ceramic tile industry has responded to large format tile trends with updated reference standards and guidelines that provide more specific definitions for large format tile as well as tighter tolerances for substrate flatness.

At Custom Building Products, we believe substrate flatness is best achieved through the application of a flowable and cementitious self-leveling underlayment (SLU) and we have developed this paper to address:

- Potential conditions in the floor subsurface and the industry's requirements related to them
- Proper specification and installation of a self-leveling underlayment over some common flooring conditions and substrate types
- The benefits of specifying self-leveling underlayment and cement-based patching and leveling compounds for all hard surface and resilient flooring products
- The performance and cost efficiencies inherent in using self-leveling underlayment materials

Enhanced Definitions for Large Format Tile and Subsurface Flatness Requirements:

The American National Standards Institute (ANSI) Specification for the Installation of Ceramic Tile stipulates that deviations in subfloor flatness should be no greater than 1/4" in 10' (Ref. ANSI A108.02 – 4.0 / 4.1.4.3.1). Before the year 2010, the Tile Council of North America (TCNA) described large format tile units as "...generally considered to be 8" x 8" and greater," with no provision for enhanced subsurface tolerances when tiles 8" x 8" or larger had been selected. However, as of 2011, subsurface tolerances for tile installation based on tile unit size have been updated in the TCNA Handbook. For tiles with all edges less than 15", the maximum allowable variation is 1/4" in 10' and no more than 1/16" in 12". For large format tiles with one edge greater than 15" and for natural stone tiles, the maximum allowable substrate variation can be no more than 1/8" in 10' and 1/16" in 24". When thin bed epoxy mortars are used, the variation can be no more than 1/16" in 36" with no abrupt irregularities greater than 1/32" (2011 TCNA Handbook). In some instances the architect or designer will require the more stringent finish tolerance, and the subsurface specification or tile specification should reflect this.



A flowable, cementitious SLU provides a finished substrate that can accept most ceramic and natural stone tile.

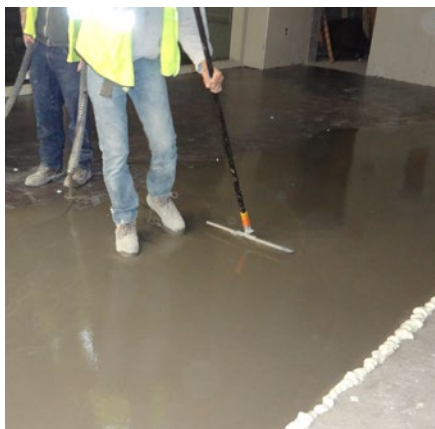


In response to the new subsurface flatness criteria, a number of tile manufacturers specializing in large format tile materials have embraced these updated floor flatness requirements, and now include references to the new guidelines in their product technical data sheets and installation guidelines. It is the responsibility of the architect or design professional to include these enhanced floor flatness requirements in the project specification. It is equally important for the architect or specifications writer to consult with the design/interiors team (and vice-versa) to ensure that the specific installation requirements and guidelines for the selected tile for the project are reflected in the tiling specification.

To achieve the required flatness tolerances, the industry is increasingly relying on self-leveling underlayment. By virtue of its working characteristics and performance, a flowable, cementitious SLU will provide flatness tolerances well within 1/8" in 10' maximum plane variation. This provides a finished substrate that can accept most ceramic and natural stone tile, including tile that maintains any edge of 15" or greater, as well as all types of resilient flooring.

Traditional Straightedge Specification vs. F-Numbers for Rating Floor Flatness

The American Concrete Institute (ACI) has adopted the so-called "f-number" system, under the ACI 117 specification, as a way of determining the flatness (and levelness as per F/L numbers) of concrete slabs. F-numbers are determined through testing procedures in ASTM E1155. These testing procedures are also referenced in ASTM F710 for The Preparation of Concrete Floors to Receive Resilient Flooring. Determining the flatness of a concrete slab using the ASTM E1155 method provides more accurate and reliable results compared to the conventional "straightedge specification" for 1/4" in 10', and 1/8" in 10' plane variation. Under ASTM E1155, ACI sets forth guidelines that require specified floor flatness be assessed within 72 hours after concrete installation to ensure accuracy. Where a typical straightedge method for plane variation indicates only where gaps occur between a 10' straightedge and finished floor, floor flatness testing procedures under ASTM E1155 provide a more quantitative method for determining the flatness and levelness of the entire concrete substrate. While various techniques exist for measuring concrete to determine f-numbers, perhaps the most common is the "dipstick floor profiler" method, in which assessments are taken at a frequency of 1 ft., in both north/south and east/west directions. Measurement lines must maintain a minimum of 11 ft. and a minimum of 34 readings per 1000 sq. ft. of floor is required. The "dipstick" testing apparatus is broadcast along a line, which measures the variation in surface elevation at 1 ft. intervals. A reading is recorded at a point when the dipstick is pivoted, and the alternate "foot" of the apparatus is placed on the slab.



Project Specifications Shall Indicate the Corrective Measures for Concrete Slabs that are not in Compliance with Project and Condition Requirements.

Appropriate floor flatness requirements for the slab based on conditions, intended usage and service requirements, can be found in ACI 302 section – Guide for Concrete Floor and Slab Construction. Although there is no exact method of comparing f-numbers to conventional straightedge testing results, the following chart can be used as a guideline to approximate values between the two:

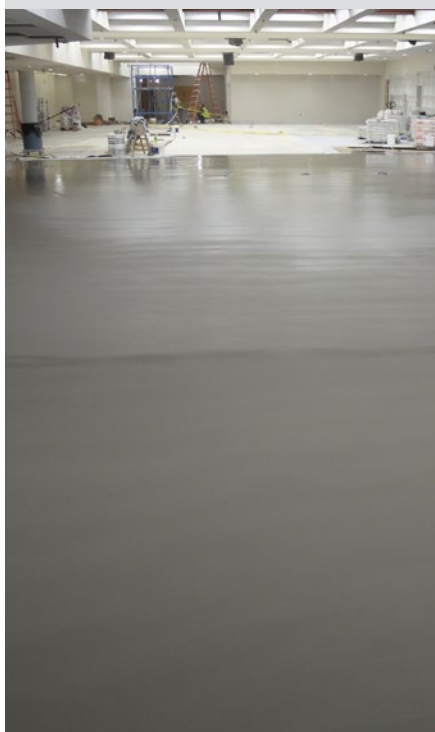
F-Number Result (F _F)	Straightedge Specification Result (Plane Variation in 10')
25	1/4"
50	1/8"
100	1/16"

F-Number Results of Self-Leveling Applications

Installing a self-leveling underlayment makes it easy to exceed the requirements of the floor covering. Using the testing procedures outlined in ASTM E1155, floor surfaces covered with a cementitious SLU have rendered f-numbers in the mid to upper 80's. The following is one example of field test results for a floor covered with CUSTOM's high performance SLU:

Minimum Required Flatness/Levelness	30 Day Result using SLU
35 / 25	86.6 / 46.2

Large format tile requires a high degree of flatness that can easily be achieved using a cementitious SLU.



Lippage, Facial Variation of Tile Units and Craftsmanship

Lippage is an unsightly and potentially hazardous defect in a ceramic and natural stone tile installation. It is a condition in which one edge of a tile is higher than the adjacent tile, which gives the finished surface an uneven appearance. When tile is selected as a flooring finish, accessibility is a key consideration, and design professionals should understand that any plane variation in the subsurface would be reflected in the finished installation. In short, a true and flat subsurface, within the flatness tolerances set forth in ANSI sections A108.01 and 108.02, will only minimize lippage conditions and any potential subsequent liability issues caused by unexpected changes in the plane of the finished floor.

Facial variation of the tile units that are being considered for the installation will also present some challenges. A tile installation with tile units maintaining any facial variation will be made even more challenging over a subsurface that maintains a change of plane outside of the ANSI and TCNA flatness guidelines. ANSI A108.02 – Section 4.3.8 stipulates that the grout joint width shall be at least three times the actual facial variation of the tile. Proper surface preparation with regard to subsurface flatness tolerances will allow for a much more efficient and less challenging tile installation, particularly when you are dealing with non-rectified tile units which maintain a facial variation, as described in ANSI A108.02 4.3.8. It is important to note that thin-set bond coats are intended solely to bond the tile to the substrate. They are not formulated for use as leveling agents.



Condition Requirements Prior to Application of Self-Leveling Underlayment

It is typically recommended that the SLU be applied in conditions where the ambient temperature is above 50° F, and not more than 90° F. To ensure the integrity of the primer, the moisture vapor transmissions rate (MVTR) from the substrate should not be in excess of 5 lbs. of water per day per 1000 sq. ft., based on a standard ASTM F1869 (calcium chloride) test, or 80% R.H., based on ASTM F2170. A moisture content that is too high will also slow the cure of the SLU and can affect the subsequent floor finish. Most floor covering manufacturers will have acceptable limits for MVTR and their recommendations must be followed. Consult with CUSTOM Technical Services for specific recommendations regarding CUSTOM'S SLU and your particular installation.

Definition, Formulation and Performance Values of Self-Leveling Underlayment

A self-leveling underlayment (SLU) for flooring consists of a blend of Portland and/or calcium aluminate cements, inorganic aggregates, copolymers and chemical modifiers, which form a flowable, self-leveling compound for leveling interior subfloors. These components form a high compressive strength and flowable cementitious compound, resulting in a flat-level surface that accepts all ceramic and natural stone tile floor finishes. Many SLU manufacturers state that select self-leveling materials also provide proper surface prep and acceptability under alternative floor finishes, such as carpet, vinyl, linoleum, resilient, and hardwood flooring. Refer to the manufacturers' published data sheets for compatibility with alternative floor finishes. Virtually all the cementitious SLU sold today is mixed with water only; no liquid acrylic-latex additive is required.

The dry re-dispersible copolymers in the manufacturers' formulas provide improved bond strength and flexibility. SLUs are formulated with proprietary copolymers and cements, which provide ultra high compressive values, in some materials in excess of 4000 psi. The high compressive value of SLU materials results in a floor assembly that consistently passes all 14 cycles on an ASTM C627 Robinson Floor Test for most applications. This "Extra Heavy Duty" rating for the finished floor is crucial for floors that are subject to heavy foot traffic and large equipment such as scissor lifts and pallet jacks. Alternative self-leveling applications, such as those over hydronic tubing or electric radiant heat systems, will provide a moderate service rating. Installations over wood joist / plywood subfloor installations can provide anywhere from a light commercial to a standard residential service rating, depending on the specific assembly detail.

The versatility of cement based self-levelers allows for SLU pours that can be applied from 1/8" all the way up to 1-1/2", or in some cases, up to 2" in total thickness. SLU materials can also be featheredged to transition to other floor finishes. Allowable thicknesses will vary depending upon the manufacturer and the specific formula. Certain proprietary formulas are available that provide an extended set for pumping. These are designed for use in high ambient temperature conditions, or over large spans when more time to float the material is required.





Cure rates of SLU materials provide for a fast setting underlayment that can accept ceramic or natural stone tile set with modified thin set in as little as 4 hours and 12 to 14 hours for resilient flooring after the SLU is poured in place. This helps to minimize project downtime and allows the work schedule to proceed more expeditiously.

Custom Building Products Answers the Challenges of the Enhanced Floor Flatness Standards with LevelQuik®.

CUSTOM preparation products are engineered to meet a wide range of job requirements and address a variety of existing floor conditions.

LevelQuik® RS Rapid Setting SLU seeks its own level within minutes and provides a early high compressive strength. This rapid setting formula can accept thin-set bonded tile applications in 4 hours or less after application. LevelQuik RS will maintain a compressive value of 4500 psi after a complete 28-day cure and can be applied up to 1-1/2" in thickness in a single pour. It can also be featheredged for smooth transitions to adjacent floor conditions and finishes. With a 30-minute working time, LevelQuik® ES Extended Set is ideal for large applications that require longer cure rates to allow for additional tooling and working after pour.



All self-leveling underlayments require pre-application of the proper primer for the job conditions. Using the right primer will ensure a strong bond to the substrate and enhance the durability of the installation. The following primers have been formulated to perform as a system with CUSTOM self-leveling underlayments.

LevelQuik® Latex Primer is recommended as a preparation for all surfaces prior to treatment with any LevelQuik® cementitious self-leveling material. LevelQuik Latex Primer dries within 30 to 60 minutes, depending upon the project conditions (including temperature and humidity), and it dramatically improves the adhesion of the SLU to the substrate while controlling subsurface porosity.



MBP Multi-Surface Bonding Primer is a single-component, water-based system engineered to deliver unsurpassed adhesion on a variety of substrates where proper bonding is difficult. Multi-Surface Bonding Primer is specially formulated with aggregates to promote mechanical adhesion on non-porous surfaces. This is a ready to use primer with one-coat application and no shotblasting or abrasion is required.



Contributions of SLUs to LEED and Green Building

One recent trend in the formulation of self-leveling underlayments is the addition of post-consumer recycled aggregates to enhance the materials' contribution to LEED certification and green building. CUSTOM has also identified the benefits of using post-consumer recycled aggregates to achieve a lighter weight formula. In some cases, the selection of a so-called



“lightweight” SLU can reduce the per square foot (psf) weight of the floor by as much as two pounds per square foot. Exactly how much an SLU can contribute to minimizing floor psf weights will depend on the thickness requirements of the self-leveling agent as a floor leveler. The thickness of the SLU will vary based on the existing conditions and thickness of the substrate, as well as transitions to other floor finishes.

Custom Building Products Responds to LEED and Green Building Requirements with LevelLite® Lightweight SLU.

Engineered with over 20% post-consumer recycled content, LevelLite® from Custom Building Products provides the highest level of green contribution under LEED 4.1 compared to any other material in the cementitious self-leveling product category. Formulated with a unique blend of high quality cements and aggregates, LevelLite provides a subsurface that is up to 2 lbs. per sq. ft. lighter than standard mortar bed installations.

LevelLite can accept a thin-set tile application in as few as 4 hours after pour, and can be applied up to 2" thick in a single pour, down to a featheredge for smooth transitions to other floor surfaces. In addition, calcium aluminate-based patching and self-leveling materials provide high compressive value and performance, resulting in a versatile surface preparation solution for a host of selected floor finishes.



Custom Building Products Delivers Patching Solutions

In addition to self-leveling underlayments and primers, the CUSTOM flooring preparation system includes patching products

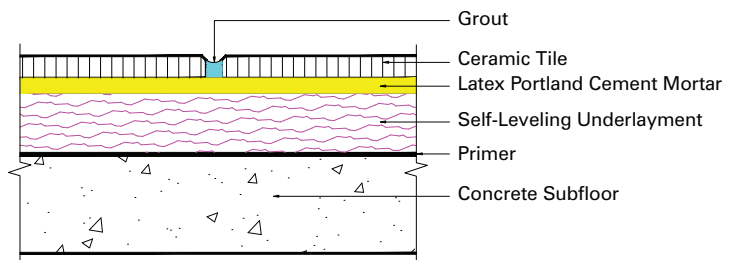
SpeedFinish™ is a fast-curing, cement-based patching compound that provides a smooth finish to a variety of substrates prior to the installation of floor coverings. SpeedFinish can be applied from a featheredge up to 1/2" thick and allows tile installation to begin in as little as 15 minutes. It can also be used as a skim coat and an embossed vinyl floor leveler.

Skim Coat and Patch is a polymer-modified, cement-based compound that provides a smooth finish to both interior and exterior subfloors. Mix with water to patch and level plywood and concrete up to a depth of 1/2". Skim Coat and Patch can also be mixed with CUSTOM Patching and Leveling Latex Additive to form an ultra high-strength system over difficult substrates.



COMMON TILE ASSEMBLY INCLUDING SELF-LEVELING UNDERLAYMENT:

TCNA F205-11
Self-Leveling Underlayment
over On Grade Concrete





Generally, a cement-based self-leveling underlayment is a suitable surface for most bonding mortars and adhesives.



Details and Guidelines for Self-Leveling Underlayments

Details and installation guidelines for floor systems that include an SLU are outlined in the Tile Council of North America Handbook for Ceramic, Glass, and Stone Tile Installation. The handbook recommends crack-isolation membranes, such as RedGuard®, Custom® 9240, or Crack Buster® Pro from Custom Building Products over concrete substrates including an SLU in order to isolate existing and new cracks in the substrate. Floor systems over SLUs need to conform to IBC, IRC and local building codes. Maximum allowable substrate deflection (prior to the application of self-leveling agent) is not to exceed 1/360 under live loads. For stone installations, maximum allowable deflection in the substrate is 1/720.

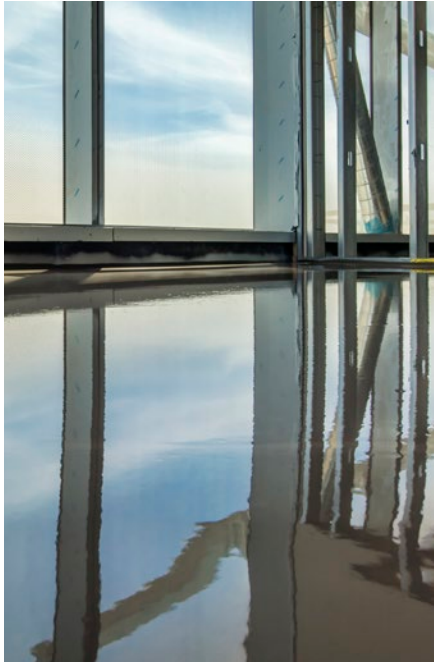
Plywood subfloor/ engineered truss joist systems can be encapsulated with a self-leveling agent. When installing an SLU over any wood framed plywood floor system, application of metal or plastic lath mechanically anchored to the plywood sheathing is essential to ensure the integrity of the self-leveling installation, with the most common reinforcement being a 2.5 lb. expanded metal lath. All plywood surfaces that are to receive self-leveling should be coated with an appropriate primer that is formulated for use with the self-leveling material. SLUs over plywood sheathing/ truss joist floors must conform to IBC, IRC and local building codes. Maximum allowable substrate deflection (prior to the application of self-leveling agent) should not exceed 1/360 under live loads. For stone installations, the maximum allowable deflection in the substrate is 1/720. CUSTOM LevelQuik RS and LevelLite SLU can be applied to truss joints or dimension lumber joist systems up to 24" o.c. spans in the floor assembly.

Compatibility of Self-Leveling Applications as Part of a Complete System Assembly.

Generally, a cement-based self-leveling underlayment is a suitable surface for most bonding mortars and adhesives. To assure compatibility, all installation products should come from the same manufacturer. All Custom Building Products cement- or epoxy-based thin-set mortar and grouting material are 100% compatible with CUSTOM SLU products. So are CUSTOM's waterproofing and crack isolation membranes, such as RedGuard, Custom 9240, Crack Buster Pro or RedGuard® Underlayment Mat. CUSTOM's ability to provide a complete system including SLU and membrane plus setting mortar (ProLite® or MegaLite®) and grout (Prism® Color Consistent Grout, CEG-Lite™ and CEG-IG™ Commercial Epoxy Grouts and Fusion Pro® Single Component® Grout) makes single sourcing from one manufacturer a simple process.

Execution and Cost Comparisons of Self-Leveling vs. Standard Mortar Bed Installations

Perhaps the biggest benefit of a cementitious self-leveling floor prep assembly is the inherent cost and labor savings it provides, particularly when compared to traditional cement mortar bed assemblies (ref. TCNA methods F111 & F112). In researching cost comparison information for this paper,



flooring contractors who specialize in both traditional mortar bed and self-leveling applications indicate that self-leveling installations cost an average of 25% to 35% less than a traditional mortar bed installation, including materials and labor costs. A two-man crew can manually pour a self-leveling application in a fraction of the time required to gauge, screed and tamp a traditional 4:1 mortar bed, as described in TCNA details F111 and F112 and ANSI A108.1. Furthermore, compared to mortar bed assemblies, the efficiency of a self-leveling application ensures that the finished product will meet much higher tolerances in regards to floor flatness, with far less labor and tooling of the material required. The cost savings noted above are indicative of this enhanced efficiency.

In consulting with floor / surface prep sub contractors, many indicate that for projects involving floors in excess of 10,000 sq. ft., self-leveling is normally broadcast with automated pumping equipment, operated by a two- or four-man crew. As the self-leveling material can be applied to specific areas of the floor using a mechanical pumping method, far less tooling of the SLU is required. Floor floats are used to broadcast the material over the floor span and required to achieve the intended floor flatness. Some manufacturers provide materials with extended set / cure times, allowing for a larger time frame in which to heal and smooth the material. This extended set is most beneficial when applying self-leveling over large floor spans in one pour. Consult with the manufacturer prior to selecting a job specific self-leveling product. Pumping of flowable self-leveling material can be executed on high-rise projects, including buildings in excess of 20 floors.

For surfaces of less than 10,000 sq. ft., self-leveling is often manually mixed on site and “bucket poured” onto the properly prepared floor finish.

Estimated per square foot weights of self-leveling installations are approximately 11 lbs. for ceramic tile, and 13 lbs. for stone installations (or 9 and 11 lbs. per sq. ft. for CUSTOM LevelLite), with a self-leveling underlayment at 1/2" in thickness, in standard applications over plywood or concrete. Mortar bed installations are typically between 19 and 21 lbs. per sq. ft. With today’s lightweight building construction, this weight differential can accommodate designer-preferred ceramic and stone tile flooring.

Typical self-leveling underlayments are ready for flooring in as few as four hours. This provides a much faster cure rate compared to a mortar bed application, which requires a minimum of 20 hours, and can be as much as 10 days, depending upon jobsite conditions (ref. ANSI A108.02 – 4.2.2.1).

In many cases a concrete floor specification (section 03450) will not provide the flatness required for the concrete substrate to be finished with a tile or stone installation. This being the case, and given the efficiencies of the SLU method, the concrete contractor and GC can pay less attention to subsurface tolerances when a self-leveling underlayment is included in the tiling spec section, as the SLU method provides the most efficient method for remedying concrete that is out of flatness tolerances.

Typical self-leveling underlayments are ready for tile in as little as four hours.





If you want to be assured of a flat surface for tile installation, self-leveling underlayments and cementitious patching materials provide:

- A cost effective floor finish compared to traditional floor prep methods such as traditional mortar beds
- Finished floors that provide flatness and levelness characteristics far greater than the requirements of TCNA and ACI 117
- Reduction in potential lippage conditions in the tile assembly.
- The availability of self-leveling products formulated with post consumer recycled content, which provide a floor with a lighter per square foot weight and contribute to LEED certification for the project.
- A subsurface finish that provides for a faster, more efficient, and higher quality tile installation.

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