Learning Proper Substrate Preparation and Quality Controls to Avoid Failures

by Donato Pompo, CTC, CSI, CDT, MBA

As the use of ceramic tile and stone has continued to grow significantly over the last decade, the number of qualified people installing these products has not come close to keeping up with the growth or demand. Therefore many unqualified people end up installing ceramic tile and stone, and there isn't enough supervision of their work to ensure successful installations. The solution is providing adequate installer training emphasizing substrate preparation and quality control. The majority of failures could be avoided if there were adequate substrate preparation and adequate quality controls during the installation.

Most ceramic tile and stone (tile) failures are related to the lack of proper preparation. These installations are only as good as the substrate to which they are applied, and the method and quality of installation used. So part of the substrate preparation is to determine whether a particular substrate is adequate for the intended use.

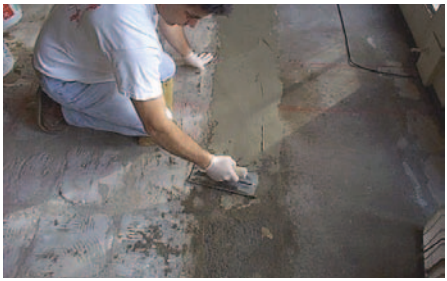
The substrate is the foundation of the installation. When this foundation is unsuitable for whatever reason, the products applied are automatically in jeopardy. Thankfully, remedies exist for correcting substrate problems, but it is important to first evaluate the substrate and take any corrective action as part of the substrate preparation process.

Substrate Quality and Suitability

Several key questions help qualify the suitability of the substrate.

Is the substrate made of a suitable material allowing for the application of the tile?

Concrete substrates are an excellent option because they are very stable and are not significantly affected by exposure to moisture. There are limitations to adhering to lightweight concrete, as it tends to have an unstable surface.



Remedies for this situation exist. One method is to first apply a thin coat of a latex modified thin-set on the clean surface, to stabilize the surface, and then apply a suitable membrane to which the ceramic tile and stone is adhered.

Wood is a questionable substrate for direct tile attachment, and is absolutely unacceptable for exterior areas or any interior wet areas. Wood may cause excessive movement when it expands from exposure to moisture compounded by temperature variations, and will warp as it dries, creating more detrimental movements. Wood can be used in dry interior areas where the deflection in the floor does not exceed $^{L}/_{360}$ for ceramic tile or $^{L}/_{720}$ for stone, but it may potentially limit the chance at a flat surface, let alone a level or sloping one.

Gypsum wallboard is similar to wood in that one cannot use it as a substrate for tile in exterior applications or wet interior area applications without special precautions. Although it is normally not used for floor applications, failures in its wall use can affect the adjacent flooring. When the interior of the gypsum wallboard is exposed to moisture, it will deteriorate

and potentially create a risk of mold.

Mold flourishes in wet environments, and gypsum wallboard is a potential food source. Water-resistant gypsum wallboard (greenboard) and fiber-reinforced gypsum panel backerboard (sometimes used on floors) can be used as substrates in shower areas when installed correctly. Unfortunately, these types of installations are not always designed or installed correctly to prevent water intrusion.

Cement backer units are the next best alternative to a concrete substrate, as they are not significantly affected by moisture exposure and provide a good surface with which to bond. However, they do not add any significant structural integrity to the installation and cannot compensate for out-of-square or -plumb wall surfaces, nor floors that are not level, flat, or sloped (as one can with a mortar bed installation).

Steel can be a suitable substrate, but special precautions must be taken to ensure an adequate bond, with the correct adhesive (epoxy adhesive), and that it will not rust in wet applications. Deflection requirements are the same as with any other surface to which tile will be attached, so the steel must be properly braced.

Is the substrate structurally stable?

Deflection in the floor must not exceed $^{L}/_{360}$ for ceramic tile or $^{L}/_{720}$ for stone. Excessive deflection is a big problem for installations over wood sub-floors and suspended concrete slabs. Structurally, these substrates

need to be designed by a qualified engineer to ensure compliance with industry standards for tile.

Is the substrate free of contamination?

Contaminated substrates are the cause of many tile bond failures. The surface must be free of dirt, dust, curing compounds, paint, and other type of coating. The concrete surface must be clean, porous, and have a textured surface to allow maximum adhesion.

Is the ceramic tile or stone suitable for the application?

Some types of tile have limitations relative to the type of application. Some stones can be adversely affected by moisture exposure such as most green marbles that can warp during installation or other stones containing pyrites which may produce rust spots. Some products will wear better than others, and may be unsuitable for certain types of applications. For example the PEI (Porcelain Enamel Institute) Rating for ceramic tile is the industry rating for the ability of glazed ceramic floor tile to resist surface abrasion. For example class V is the highest rating qualifying suitability for most commercial applications such as malls. The stone industry uses an Abrasion Resistance test to qualify suitability. The Marble Institute of America (MIA) states that marble and limestone should have an index of at least 12 in heavy traffic areas. Some products do not possess enough slip resistance for wet conditions, while others are too

textured and cause maintenance issues. Suitability must be qualified with quantitative industry standards. However, installation systems can be designed to compensate for some ceramic tile or stone weaknesses (i.e. moisture-sensitive stones must be installed over a suitable moisture barrier, and may require installation with a waterless adhesive, such as an epoxy).

Floor preparation for tile involves understanding the characteristics and limitations of the finished product, as well as evaluating the substrate and installation system to ensure they are suitable for the intended application and use. Any substrate problems then need to be corrected with a legitimate remedy meeting industry standards. Industry associations such as Tile Council of America (TCA) and MIA can provide information and some guidelines, and the manufacturers of the installation systems can provide system specifications and warranties. Industry consultants can be useful in helping to assess project needs and developing project specifications.

Liability and risk varies with the quality of the substrate and installation method. Here are some of the most common problems leading to tile failures, along with some suggestions for avoiding them:

Problems and Prevention

Mold

The presence of mold signifies that a problem exists; specifically, moisture is being improperly managed. To thrive,

mold needs a comfortable temperature of about 20 C to 30 C (68 F to 86 F) with a relative humidity of greater than 60 percent, not to mention a good food source. The key to preventing this and other water damaging problems is to fully manage moisture by ensuring proper slope to drains (at both membrane level and finished surface), correct drain assemblies, proper waterproofing, and sealing of transition areas and movement joints with quality sealants. The risk is further diminished with the use of products that do not deteriorate or contribute to the growth of mold when exposed to moisture.

Cracking

Cracks are nature's way of creating its own movement joints. As rigid materials, concrete, ceramic tile and stone can only move so much before causing damage. All surfaces and materials move within themselves or as a differential to the material to which they are attached or next to. The movements may be caused by deflection, moisture absorption causing expansion, thermal expansion or contraction or any combination of the above.

The ceramic tile and stone industry has established limitations and standards for the architect/engineer when designing movement joints into all interior and exterior surfaces. In general, TCA method EJ171-03, Movement Joint Design Essentials, suggests having movement joints every 7.3 m to 10.9 m (24 ft to 36 ft) for interiors (unless next to a window or skylight, where it is then treated as an exterior application), and every 2.4 m to 3.7 m (8 ft to 12 ft) for exterior floors or walls. Movement joints are often left out of the details because designers feel they detract from the aesthetics of the installation. When planned during the design of the floor, however, movement joints can easily be incorporated without compromising the design. In fact, they frequently can be used to accentuate key area features.

As an installer you assume liability if you don't install expansions joints. Make sure the architect understands it is their responsibility to specify the detail and exact locations of expansion joints on a drawing.

Deflection failures

Floor deflection must not exceed $^{L}/_{360}$ for ceramic tile or $^{L}/_{720}$ for stone.

These measurements must be determined and designed by the project engineer. Problems are normally caused by compounding factors. It is likely more than one factor causing a failure. In fact, it is normally the combination of several different factors. Thus excessive deflection with lack of movement joints increases the risk of failure. It is beyond the installer's responsibility to determine deflection in a floor, but as with expansions joints, you assume liability if you don't make sure it was engineered to meet industry standards before you start the installation. As stated earlier, it is the responsibility of the architect to make sure the assembly was properly engineered to meet industry standards prior to beginning the installation.

Bond failure

When an adhesive (cement based or otherwise) bonds to the tile or stone but not the substrate, or vise versa, then some contamination is likely interfering. Curing compounds used to slow cure the concrete to minimize cracking is ceramic tile and stone's number one enemy. These compounds are supposed to dissipate with time, but never soon enough. Then there is dirt, construction dust, various oversprays, laitance (an accumulation of fine particles on the surface of fresh concrete due to an upward movement of water), and other types of contamination. Substrates must be cleaned and/or scarified prior to installation to ensure an adequate bond. There is a very simple qualitative test (not quantitative) that can be per-

formed on concrete substrates to determine if there may be a potential bonding problem (red flag alert). Simply apply a small amount of water (about the size of a quarter) and watch to see how readily the concrete absorbs it. If it immediately absorbs the water, then it is likely contaminate free and only needs to be cleaned. If it immediately beads up (like water on a newly waxed car), there is definitely some sort of a contaminate on the surface and it needs to be removed by scarifying the concrete. If the concrete doesn't absorb all of the water within a few minutes the concrete should be scarified to ensure an adequate bond. Bead blasting is a very effective and popular method of scarifying floors today.

Flatness

To ensure adequate drainage, or to compensate for an irregular surface, the substrate floor should be covered with a mortar bed to create the prescribed slope, or to level it when necessary. Whether at a slope or level, the floor needs to be flat for a quality installation. A major problem for installers is when architects specify a direct-bond application to the poured slab to avoid adding a mortar bed to save money, or when the floor is not designed with enough room to accommodate the mortar bed's height.

Architects often expect the slab to be

flat enough, or the installer to compensate for any irregularities in the floor during installation. In truth, the slab is often not flat enough without special preparations and added costs. The substrate ends up having highs and lows, all of which can be adjusted... for a price. The highs need grinding or bush hammering and the lows need filling. Patches and self-leveling products allow for adjustment, but again, at a cost not normally provided for in the specification.

The result of a floor not being flat is the installation will be more labor intensive and the floor's irregularities can telegraph into the tile or stone (even with conscientious installers). Floors should either be designed with mortar beds, or the specifications should allow the installer's bid price to include measures for properly preparing and flattening the floor. Some floors can be excessively out of level and not flat, so it is reasonable to limit the installer's bid. The specs should call for no more than an average of 13 mm (0.5 in.) of underlayment. The installer would have to be compensated for anything exceeding this amount while trying to achieve 6 mm in 3 m (0.25 in. in 10 ft) American National Standards Institute (ANSI), ANSI A-3.1.4.1.1. When the floor is not flat, as an installer, if you don't provide your client with corrective options you assume the responsibility to correct the floor at your own expense or assume the liability. Innovative new laser technology is great for the tile contractor to easily and demonstrably show to their client how far a floor is out-of-level or out-of-flat.

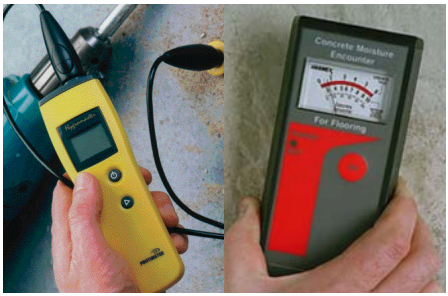
Moisture

The most destructive force in the construction industry is moisture in one form or another. Mold can't live without moisture. Some natural stones are moisture sensitive and can stain, spall, warp, and show other types of

deterioration from exposure to excessive moisture. Efflorescence (a whitish deposit on surface) is the result of soluble salts dissolving and traveling with the moisture to the surface. A hydrostatic condition is when the water source is higher than the floor surface. This situation is mentioned much more often than it actually occurs. The source of moisture is more likely coming from improper landscape drain off, from broken pipes, improper waterproofing, from high water tables or excessive moisture trapped in or under the slab for one reason or another. Vapor transmission is when moisture travels in the form of a gas from a higher concentrated source to the air at the surface where it diffuses into the atmosphere. Too much vapor transmission can cause problems, particularly with resilient, laminates, hardwood and carpet floor products. Ceramic tile is much more resistant to moisture problems, but it does have its limitations; particularly with the use of impervious tile, membranes and grouts. Where as other floor covering products have standardized the maximum limitation to 3 lbs./1,000 sf/24 hrs., as measured by the calcium chloride test (ASTM F-1869), ceramic tile and stone have not set any industry standards in this area. There is a Materials & Methods Standards Association (MMSA) committee working on creating ASTM standards for moisture, and there is a Ceramic Tile Institute of America (CTIOA) committee reviewing the use of moisture meters. Stone is much more sensitive to moisture and the MIA recommends that all on-grade concrete floors have a moisture barrier to minimize potential problems. Hydrostatic conditions are never acceptable.

The question to the installer is how do you determine if the substrate has too much moisture? It is a complex issue and the General Contractor (GC) should be responsible for determining

if the concrete has too much vapor transmission. The GC should hire a qualified testing company to do a Calcium Chloride test to measure vapor transmission, and they should be the ones to determine if it is suitable. Remember our industry has not set standards, although some manufacturers of tile and installation products will have an opinion that will limit their warranty.



For an installer to determine if there is a moisture problem or not (so he can raise a red flag), there are several moisture meters on the market that will measure moisture in the concrete, gypsum or wood substrate. Some meters use the principle of electrical impedance measurement to give an accurate non-destructive moisture reading to a depth of approximately 1/2 inch. Others use non-invasive pinless radio frequency to measure moisture at 3/4 inch depth. Both types also have a hydrometer probe meter where they drill into the concrete and measure relative humidity and temperature following the relatively new ASTM F-2170-02 method for measuring mois-

ture. The idea is you can map your floors to see a view of relative moisture at that time. If you get excessive readings, then you can have the Calcium Chloride test performed to determine actual vapor transmission rates or perform the hydrometer test to measure the moisture within the concrete over time.

Quality Assurance and Control

The key to a successful installation is to have clear and concise installation specifications with job-specific quality assurance and quality sections. First, the right ceramic tile or stone for the respective application must be selected to ensure suitability. Considerations must be made for:

- Resistance: slip, abrasion (wear), and absorption (stain);
- Freeze-thaw stability for cold climates;
- Durability: compressive strength or specific gravity and density;
- Maintenance: moisture and chemical sensitivity and surface texture.

Next, the best installation system to be used with the product over a quality substrate must be specified. Waterproof or crack-suppression membranes should be included where needed for both immediate protection and long-term insurance. The lower the performance of the products and methods specified, the higher the risk of liability. One should strive to exceed, not just meet, industry stan-

dards by calling out performance specifications. (When one considers imperfect site conditions and labor, why call out or use reference standards representing the lowest level of acceptable performance?)

The Construction Specifications Institute's (CSI's) *MasterFormat*™ Division 1–General Requirements, Section 01420 calls out Quality Assurance in general terms, as does Section 01430, which calls out Quality Control guidelines. This should be coordinated with *SectionFormat's*™ Part 1 – General to qualify the components of the application from labor to product.

This step ensures suitability and sets the stage for a pre-installation meeting. The meeting is very important, as it provides the opportunity for all work-related subcontractors to coordinate their work and communicate their understandings and intentions. This meeting should involve the architect, general contractor, manufacturer, owner's representative and tile contractor.

Part 2 – Products should not only call out industry standards, but performance qualifications that can be measured and substantiated to ensure the quality of the products and their fabrication.

The most overlooked part, Part – 3 Execution, should specify not only installation methods in recognized publications, including preparatory actions, post-installation protection and cleaning, but should provide a Quality Control Plan specifically stating the process, testing, and type and timing of inspections to be done during installation to ensure success. One should not leave quality control accountability to the installer, as is normally the case, but rather designate an independent inspector or owner representative to implement the quality control plan.

Remember, the lower the perform-

ance of the products and methods specified, the higher the risk of liability. This risk is compounded when quality assurances and controls are not clearly spelled out in the specifications. Everyone pays when there is a problem, even when it is only with their loss of time and reputation.

Conclusion

Use of ceramic tile and stone has grown substantially over the years and there is no slow down in sight. We need the combination of more training and more installers to supply the demand for qualified installers, which will lead to more successful installations and minimize failures. Ceramic tile and stone failures hurt all of us in our industry; not only due to excessive cost for repairs or replacements, but it tarnishes our industry's image in the eyes of potential buyers. The end user seeks out our products not only because they provide a very pleasing and prestigious look with many design options, but because our industry provides an enduring surface that can last the life of a building when installed correctly. That is what the customer wants, that is what they pay for, and that is what they should get. Quality specifications and proper substrate preparations are key to lasting installations, but both the architect and the installer have to be taught to understand the extent of this process. We as an industry need to invest in our employees and our future by providing continuous training to our labor force.

Author

Ceramic Tile Consultant, Donato Pompo CTC CSI CDT MBA is the founder of Ceramic Tile and Stone Consultants (CTaSC). Donato has over 25 years experience in the ceramic tile and stone industry from installation to distribution, to manufacturing of installation products. CTaSC provides services in Job Problem Investigations, Quality Control Services for products and installation methods to include writing architectural specifications, Training Programs to include on-site training, and online courses from his new University of Ceramic Tile and Stone (UofCTS) campus, Market Research and Outsourcing Services and Business Planning services. You can reach Donato by visiting his web site at www.CTaSC.com, or e-mail at dvpompo@CTaSC.com, or by calling 619-669-2967.