Substrate Prep & Quality Controls for Ceramic Tile & Stone

Photo of Brass Mill Center Mall (Waterbury, Connecticut) courtesy Laticrete International.

by Donato Pompo, CTC, CSI, CDT, MBA

The use of ceramic tile and stone has continued to grow significantly over the last decade. At StoneExpo 2002, the executive director of the Tile Council of America (TCA), Robert E. Daniels, said the tile industry has seen its sales double in the last seven years to 2.274 billion square feet in 2001. According to U.S. Department of Commerce (DoC) figures, however, the number of people installing tile floors ('tilesetters') has increased by only 25 percent. Stone has experienced similar explosive growth, particularly in recent years.

Compounded by the shortage of qualified installers, most ceramic tile and stone (CT&S) floor failures are related to the lack of proper floor preparation. These floors are only as good as the substrate to which they are applied and the method of installation used. Substrate preparation, in turn, will 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, then the products applied on top are automatically jeopardized. 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 floor 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 CT&S?

Concrete substrates are always best because they are the most 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, but remedies for even this situation exist. One method is to first apply a thin coat of a latex-modified thin-set on the clean surface to stabilize it, then apply a suitable membrane to which the ceramic tile and stone can adhere.

Wood is always a questionable substrate for direct CT&S attachment, and is absolutely unacceptable for exterior areas or any interior wet areas. Wood causes excessive movements 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 greatly limits 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 CT&S 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 adjacent flooring. When the interior of the gypsum wallboard is exposed to moisture, it will deteriorate and potentially create the risk of mold.

Mold flourishes in wet environments, and gypsum is a good source of food. 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 often designed or installed correctly to prevent water intrusion.

Cement backer units are the next best alternative to a concrete substrate, as they are unaffected 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/plumb wall surfaces, or floors that are not level, flat, or sloped (as one can with a concrete mortar bed installation).

Steel can be a suitable substrate, but special precautions must be followed to ensure an adequate bond with the adhesive (epoxy), and that it will not rust in wet applications. Deflection requirements are the same as with any other surface to which CT&S 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 CT&S.

Is the substrate free of contamination?

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

Is CT&S suitable for the application?

Some types of CT&S have limitations relative to the type of application. Some stones can be adversely affected by moisture exposure (*i.e.* green marbles are known to warp during installation, and some other stones containing pyrites may produce rust spots). Some products will wear better or worse than others, and may be unsuitable for certain types of applications.[1] 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.* some moisture-sensitive stones must be installed over a suitable barrier, and may require installation with a waterless adhesive, such as an epoxy).

Floor preparation for CT&S 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 TCA and the Marble Institute of America (MIA), provide information and some guidelines, but it is the manufacturers of installation systems who provide specifications and warranties.

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

Problems and prevention

Mold

Mold is a symptom of a problem; 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, like gypsum wallboard and some non-cement-based adhesives. The key to preventing this and other water damage problems is to fully manage moisture by ensuring proper slope to drains, drain assemblies, waterproofing, and the 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, 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, and thermal expansion or contraction.

The CT&S industry has established limitations and standards for the architect/engineer (A/E) 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.

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. Thus, excessive deflection with lack of movement joints increases the risk of failure.

Bond failure

When adhesive 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, and other types of contamination. All substrates must be cleaned and scarified to ensure an adequate bond.

Flatness

To ensure adequate drainage, or to compensate for an irregular surface, the substrate floor should be covered with a mortar to create the prescribed slope, or to level it when necessary. Either way, 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 the mortar bed and save money, or when the floor is not designed with enough room to accommodate the mortar bed's height.

Architects often expect the poured slab to be flat enough, or the installer to compensate for any irregularities in the floor during installation. In truth, the poured slab is never 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 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 will translate 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.

Quality assurance and control

The key to a successful installation is to have clear and concise installation specifications with job-specific quality assurance and control 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; and
- maintenance: moisture 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 standards by calling out performance specifications. (When one considers imperfect site conditions and labor, why call out 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, and owner's representative.

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 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.

The lower the performance 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 their time and reputation.

Conclusion

Ceramic tile and stone have been a valuable flooring option for well over 5000 years, and with good reason. They not only provide a very pleasing and prestigious look with many design options, but an enduring floor lasting the life of a building when installed correctly. Quality specifications and proper floor preparations are key to lasting installations.

Notes

[1] For example, the Porcelain Enamel Institute (PEI) rating for ceramic tile represents its ability to resist surface abrasion. Class V is the highest rating, making those tiles suitable for most commercial applications, such as malls. The stone industry uses an abrasion resistance test to qualify suitability. The Marble Institute of America (MIA) suggests marble and limestone should have an index of at least 12 in heavy traffic areas.

Additional Information

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MasterFormat No.

01430–Quality Assurance
01450–Quality Control
09305–Tile Setting Materials and Accessories
09310–Ceramic Tile
09330–Quarry Tile
09340–Paver Tile
09380–Cut Natural Stone Tile

UniFormat No.

C3020–Tile Floor Finishes
C3020–Stone Flooring
Z1020–Quality Assurance and Control

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Abstract

Floor preparation is key to ceramic tile and stone installations, but this is just one of several facets to be called out in the specifications. From suitable products to adequate substrates, a thorough and complete specification following Construction Specifications Institute (CSI) principles is required for a successful installation.