More than One Way to Skin a Building

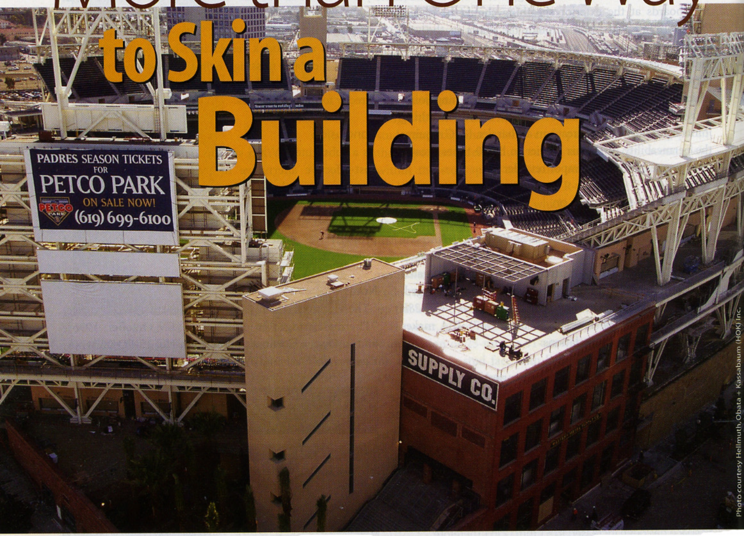

Photo courtesy Hellmuth, Obata + Kassabaum (HOK) Inc.

Ceramic tile, brick, and natural stone veneers

by Donato Pompo, CTC, CSI, CDT

Ceramic tile, brick, and natural stone are among the most enduring materials used for exterior veneer claddings. The facades are durable, fire resistant, display good insulative properties, and require minimal maintenance. Although they cost more to install, their life-cycle cost averages are much lower than other options, given they can (theoretically) last for centuries. However, these veneers are only as good as the substrate to which they are affixed, as well as those installing them. Effective quality control can minimize risks.

Although brick, ceramic tile, and stone have been used for centuries, current practice involves thinner products and better attachment methods. Thin products mean less weight, quicker installations, lower costs, and more design flexibility. Dimension stone, for example, is cut and finished to specification—usually 20-mm to 50-mm (0.75-in. to 2-in.) thick and several feet long and wide. The preferred thickness for exterior veneer applications is 30 mm (1.18 in.), with a maximum facial surface of 1.9 m^2 (20 sf) and approximate weight of 88 kg/m^2 (18 psf).

Modular stone tile is usually about 13-mm (0.5-in.)

thick. It has a surface area up to 0.37 m^2 (4 sf) and weighs around 34 kg/m^2 (7 psf). Ceramic tile normally used for exterior veneers is also less than 13-mm thick and weighs less than 24 kg/m^2 (5 psf). Thin brick emulates a 'full' brick look, so its unit size is normally about 56 x 191 mm (2.2 x 7.5 in.) in facial dimensions, with a thickness of about 10 mm (0.4 in.) and weight of 15 kg/m^2 (3 psf).

A case for adhered veneer

Several years ago, I was involved in developing the specification for the exterior veneer at San Diego, California's new ballpark stadium—PETCO Park (Photo 1).

Antoine Predock designed the stadium while HOK Sport + Venue + Event served as project architect. The general contractor (GC) was a joint venture under the name San Diego Ballpark Builders. HOK wanted a cementitious backer unit (CBU) installation for the 14,865 m^2 (160,000 sf) of Indian sandstone. Unit sizes ranged up to 610 x 610 x 16 mm (24 x 24 x 0.6 in.), and would be installed as high as 40 m (130 ft) off the ground.

In August 2000, met with Klaser Tile (the company bidding the contract), along with representatives from the GC, HOK, and the owner to discuss the trade-offs between

Photo 1

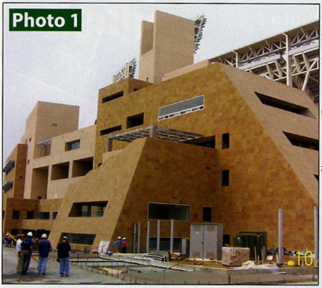

Photo courtesy Terraneo Marketing Concepts

CBUs and scratch-and-brown coats (SBCs). The latter option was selected, so several mock-ups were created to determine which SBC would be used. A final mock-up was then built and tested vigorously—as per the requirements of Wiss, Janney, Elstner Associates (WJE) engineers—to ensure the SBC selected would survive the most severe conditions.

Photo 2

Photo courtesy Ceramic Tile And Stone Consultants

Photo 3

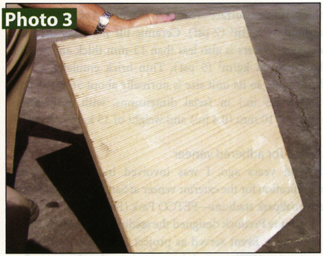

Photo courtesy Klaser Tile Co.

A full-size mock-up comprising adhered veneer was built by project subcontractors and tested per WJE procedures at Smith-Emery testing facility in Los Angeles, California (Table 1, page 54). Testing showed the stone facade assembly was adequate for the wind and seismic loads specified for the ballpark. Considering the tests pushed the assembly to failure exceeding 250 percent of design load, and racking to ±136 mm (5.35 in.) without any failure, confirms how well-executed adhered veneer can and should perform.

Back at the site, a number of QC procedures were put into place. In addition to the usual inspections, the GC assigned someone to pull off randomly selected, freshly placed stones to ensure 100 percent thin-set coverage. Additionally, those setting the stones would re-inspect backs for voids two or three times during the installation process (Photo 2).

Klaser Tile also had the Indian sandstone backs ground for a larger, flatter, more grooved surface area, which provided more bonding area for a better mechanical attachment (Photo 3). For the soffit process, crews countersunk screws in the stone units then plugged them with cores drilled from other pieces. Bill Klaser of Klaser Tile says this process was unnecessary—the large stones had so much suction, they could not move once installed on a soffit—but it made the GC feel a lot better knowing the 18-kg (40-lb) stone pieces were mechanically attached.

Application methods

Many application methods exist for these materials, but in all cases the structural framework and products must suit the application. Every system needs to be engineered for specific factors, like weight, wind load, back-up material, structural flexure, seismic conditions, thermal/moisture movements, and weather resistance. They must always meet required building codes.

The *Uniform Building Code (UBC)* and Building Officials and Code Administrators (BOCA) have set performance standards for these applications in Chapter 14, "Exterior Wallcovering," but local building departments make the final decisions and exceptions. For example, adhered veneer units must be less than 41-mm (1.6-in.) thick and 914 mm (36 in.) in the greatest dimension. They must also be less than 0.46 m^2 (5 sf) in total area and weigh under 73 kg/m^2 (15 psf). (An exception to these conditions is when the veneer weighs less than 15 kg/m^2 [3 psf]).

Height is limited by the structural framework. The attachment provided for the veneer must withstand a shearing stress of 344 kPa (50 psi). Larger units need to be mechanically attached to meet these codes.

Products/applications also need to meet industry standards. For natural stone, the Marble Institute of America (MIA) publishes guidelines in their *Dimension Stone Design Manual,* citing ASTM International standards. For instance, granite dimension stone used for exterior veneers must meet ASTM C 615-99, *Standard Specification for Granite Dimension Stone* (other standards exist for limestone, marble, slate, travertine, serpentine, and quartz-based stone). MIA also states deflection in stone applications must be L/720 or less.

Ceramic and modular stone tile standards revolve around the Tile Council of North America's (TCA's) *Handbook,* which provides acceptable installation methods and details, with references to American National Standards Institute (ANSI) standards. TCA states deflection in ceramic tile applications must be L/360 or less. The Ceramic Tile Institute of America (CTIOA) and the National Tile Contractors Association (NTCA) support these standards and provide additional guidelines, which should be specified in the Quality Assurance section of the respective division (*i.e.,* 04400–Stone, 09380–Modular Stone Tile, and 09300–Ceramic Tile).

Mechanical-anchored veneer

Mechanical fasteners, continuous metal extrusions, clips, dowels, or wire ties are among the various methods for mechanically anchoring larger stone units. (Dimension stone usually needs to be 30-mm (1.18-in.) thick to accept mechanical anchors.) Anchors support the unit's weight, resist live loading, and allow an individual unit's position to be adjusted. Stone units can be handset installed, or placed as prefabricated panels. In the past, anchor attachment methods were assumed to provide greater safety than adhered methods, but at a considerable cost. With today's improved products, methods, and controls, however, adhered techniques are considered safe.

Exterior ventilated wall systems have been used in Europe for the past 30 years, and are now gaining some interest in the United States. They can be used with ceramic tile, dimension stone, or modular stone tile, and rely on a structural wall with an aluminum frame and vertical tubular studs secured by means of adjustable brackets. A 50-mm to 60-mm (2-in. to 2.4-in.) wide air space between the structural wall and exterior veneer provides the ventilation, which helps manage moisture and increase energy savings.

Adhered veneer

A number of methods exist for adhering veneer units, be they ceramic or modular stone tile, or thin brick. (There are special products and methods for adhering dimension stone units.) Generally speaking, the same methods used in individual unit installations apply to prefabricated panels.

Substrate considerations

Given the appropriate structural framework is in place, typical substrates used for attaching veneer units to a structural wall are concrete masonry units (CMUs), cast-in-place/precast concrete walls, pre-fabricated wall panels, concrete scratch-and-brown coat (SBC), and cementitious backer units (CBUs).

The sub-surface must be properly prepared to ensure a successful installation. It must be sound, dimensionally stable, clean, and free of curing compounds and other contaminates. The wall must be plumb, with surface variation not exceeding 6 mm over 3 m (0.25 in. over 10 ft). While it is possible to bond directly to CMU and cast-in-place/precast walls, one should first apply SBC with a properly placed moisture barrier. When installing over structural stud walls, veneer units are normally bonded

Table 1 Wiss, Janney, Elstner Associates' (WJE's) PETCO Testing

Tests performed	Results
Thermal cycling test	No visible distress to stone or assembly
ASTM E 331* water testing using 479-Pa (10-psf) negative pressure	Water penetration only along top beam attributed to the incorrectly installed testing perimeter condition
ASTM E 330** cyclic wind pressure testing to 100-percent design wind load	No visible distress to stone or assembly
ASTM E 331 water testing again using 479-Pa negative pressure	Water penetration only along top beam attributed to the incorrectly installed testing perimeter condition
Racking test of 23 mm (±0.89 in.) to measure maximum movement in-plane	No visible distress to stone or assembly
ASTM E 330 cyclic wind pressure testing to 150-percent design wind load	No visible distress to stone or assembly
Racking test of 136 mm (±5.35 in.) to measure maximum movement in-plane	No visible distress to stone or assembly
Wind pressure testing to failure	Failure occurred at 4.2 kPa (87.5 psf) negative pressure (250 percent of design load). Screws used to fasten the studs' bottom track had sheared.

* ASTM E 330, *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference.*

** ASTM E 331, *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference.*

directly to CBUs. One must first attach sheathing to the studs for added dimensional stability and to form a barrier for the building. Considering the area's climatic conditions, the appropriate moisture barrier is placed and CBU attached.

CBU applications are considered a lighter and less expensive installation system, and proper management can compensate for the inherent trade-offs. For example, the CBUs surface is only going to be as plumb and consistent as the studs to which it is applied. Surface variations can be minimized (to a degree) by filling low areas with the polymer- or latex-modified thin-set adhesive used to set the veneer units (this step is often skipped when irregular stone is used). With an SBC, however, installers can easily compensate for any stud irregularities to achieve a plumb surface.

The number of joints between CBU sheets are another trade-off. While 914 x 1524 x 13 mm (36 x 60 x 0.5 in.) is a common CBU size, the 1219 x 2438 x 13 mm (48 x 96 x 0.5 in.) sheets are often used on exterior veneers because they line up better with studs and have fewer joints. CBU sheets should be installed staggered-joint with those of adjacent rows and any underlying materials to minimize movement. The joints should be filled and taped with a 51-mm (2-in.) fiberglass fiber mesh tape.

A liquid or trowel-applied waterproofing membrane is often applied over the CBUs for added moisture protection and to minimize potential efflorescence. With an SBC, installers not only avoid this problem, they have a more structurally sound surface.

The veneer installation method over these various substrates is very similar, with some exceptions. Ceramic tile tends to be more consistent in size, and does not require its surface to be sealed (with fired-on glaze). Stone, on the other hand, can be consistent or very inconsistent in thickness, facial sizing, and warping. Stone surfaces usually need to be sealed, particularly when they are not of a dense polished stone.

Thin brick can vary significantly in size and warping, which is to be expected. While the material can be very dense, it is nonetheless quite porous, and should be sealed before installation. Efflorescence coming through grout joints or porous surfaces can be minimized with sealers and by applying waterproofing membranes on the substrate receiving the thin veneer.

Ultimately, the most important part of a project is having adequate (and specific) quality assurance/control (QA/QC) specifications. These sections of the specification are often left up to the subcontractor to implement, which can be a costly mistake. When written correctly, they become critical to a project's success, regardless of the application method.

Despite the fact they are the most conducive (and affordable) options for installing these various veneers, scratch-and-brown coats and cementitious backer units are frequently misunderstood. However, once the architect/ engineer (A/E) familiarizes himself with them, the sooner he can add them to his repertoire of proven performers.

Scratch-and-brown coat

SBC is the preferred method for an exterior veneer, as per TCA W 241-03, *Interior/Exterior Application on Wood/Steel Framing* (Figure 1, page 56). While a more substantial application, it does afford more control over the finished product. On larger projects, it is practical to have the lath and plaster trade install the SBC, which uses pumps to apply the cement base coats quickly and inexpensively. The only real problem is they may work with their own trade-specific standards, which could differ from what is required of the ceramic tile and stone trade. Flatness for portland cement base is 6 mm over 1.5 m (0.25 in. over 5 ft) for the plasterers' brown coat, while the ceramic tile industry subscribes to a 6 mm over 3 m (0.25 in. over 10 ft) standard.

Moisture barrier

Moisture barriers should be specified. Lathers typically use asphalt-saturated kraft paper—grade D (breathable) or B (vapor retarder)—to protect building interiors from moisture intrusion. The tile industry normally calls for 7-kg (15-lb), asphalt-saturated felt or 0.1-mm (0.004-in.) polyethylene film.

The Technical Services Information Bureau (TSIB) recommends applying the paper and lath in two separate applications. A few problems can occur when using a paper-backed, expanded-metal lath, such as the improper lapping of the lath sandwiching the paper. In fact, no paper should be between the two lapping lath pieces, as this can lead to cracking. Additionally, the paper-backed lath tends to get torn by the lath's sharp edge during handling. All horizontal and sloped surfaces must be waterproofed with an appropriate membrane.

Flashing

An important step for managing moisture is to properly flash transition areas: outside/inside corners, parapets, bottom wall flashing/weeps, window sills, and movement joints. Normally formed from galvanized sheet metal, bituminous membranes, or a combination of the two, flashings should be lapped and sealed, and continuous around inside and outside corners. Horizontal surfaces (*i.e.*, windowsills, ledges, copings, caps) should be wrapped with a membrane whose surface slopes away from the building.

Another important detail is the foundation weep screed at the wall base. Moisture travels into cement grout joints through the cement thin-set adhesive and mortar substrate. With gravity's help, excess moisture has an escape route through the weeps (which need to be kept off the ground, per *UBC*). The designated QC inspector must check these transition treatments, and the specifications should clearly show and call out these details.

Figure 1

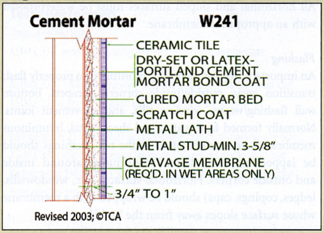

Figure courtesy Tile Council of North America

Figure 2

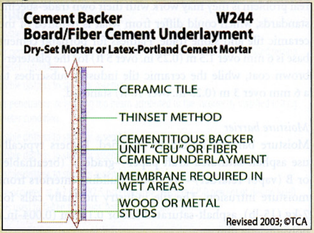

Figure courtesy Tile Council of North America

Movement joints and sealants

Per TCA EJ171-03, *Movement Joint Design Essentials,* movement joints should be placed every 2.4 m to 3.66 m (8 ft to 12 ft) in each direction, and situated at all plane changes to include inside/outside corners. To some degree, both the veneers and their substrates move as a result of thermal/moisture movements and dynamic forces. The differences in movements between disparate materials compound the problem, making movement joints critical.

Minimum movement joint width is 13 mm (0.5 in.) for those 406 mm (16 in.) o.c., but other factors should be considered. For instance, minimum widths must be increased 1.5 mm (0.06 in.) for each 15-degree F tile surface temperature change greater than 38 C (100 F) as the difference between the lowest and highest temperatures during the year. The project engineer should specify the movement joints and where to place them, as it is not within the installer's qualification to determine their exact locations or type.

The ideal movement joint for thin veneer is a two-piece, No. 40 metal adjustable screed, which needs independent framing for attachment. Lathers normally want to use a No. 15 control joint, which limits movement and does not require independent framing, but the two-piece type can accommodate contraction, expansion, and shear stress movements.

The correct sealant is required to get the full potential out of movement joints. Not only do they need to accommodate movements, but sealants also have to keep moisture out while withstanding the elements. The A/E must select the correct sealant to ensure maximum adhesion and durability, and compatibility with other materials. Urethane and 100-percent structural silicone sealants are generally used for exterior applications.

Backer rod use is critical for achieving a sealant's full performance, as it prevents the sealant from adhering to the joint's bottom, and keeps it thin enough to accommodate maximum movement within the joint. Joints should be cleaned and have a primer applied prior to filling, with tooling prescribed to facilitate drainage and prevent moisture collection.

Metal lath

Using the correct metal lath type for SBC reinforcement is necessary, with CTIOA recommending a 1.84-kg/m^2 (3.4 psy) self-furring, galvanized diamond-mesh lath. It should be attached with screws/staples that penetrate into wood framing not less than 16 mm (0.6 in.), and through metal supports adaptable for screw attachment not less than three thread turns. Screws should be placed every 152 mm (6 in.) vertically and horizontally along the studs. Screw penetrations through the moisture barrier are considered sealed when under compression (for the vertical surface), but all sloped and horizontal surfaces must be fully waterproofed. Whether moisture barrier paper is attached to the lath or not is unimportant, provided the paper does not get punctured. It should be lapped a minimum of 51 mm (2 in.) metal-to-metal and paper-to-paper.

Cementitious backer units

The CBU is a legitimate substrate and method for applying ceramic and modular stone tile, and thin brick. Here, too, larger project practicalities call for members of the lath trade to install CBUs, as they can do it faster and for less cost. Flashings, movement joints, and sealants are incorporated into the installation in the same manner as SBCs. Again, it is important to have adequate specifications and quality controls to ensure a good installation.

Figure 3

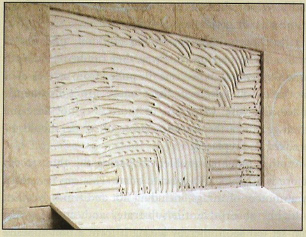

Figure courtesy Ceramic Tile And Stone Consultants

Not all cementitious backer units are recommended for exterior work—it is important to get the manufacturer's recommendations and warranties for these applications, and follow their installation instructions (along with TCA method W244-03, see Figure 2).

Moisture barrier

Moisture barriers must be specified for type and placement by project engineers. Sheathing should be provided over studs to provide added stability and minimize sagging between them. All horizontal and sloped surfaces must be waterproofed. Bituminous membranes can be used to waterproof, so penetrations from attaching the metal lath get sealed, while other special membranes can be applied over the substrate for affixing the veneer.

Attachment

Attachment is a critical installation step. As described above, CBU sheets must be placed staggered-joint with those of adjacent rows and the underlying substrate. The CBU should be fastened on framing every 203 mm (8 in.) o.c. with perimeter fasteners between 10 mm and 16 mm (0.4 in. and 0.6 in.) from ends and edges.

Fasteners must be corrosion-resistant steel screws, 32-mm (1.25-in.) long for 13-mm (0.5-in.) thick CBUs. Different CBU products call for different spacing between sheets. Joints should be filled with a modified thin-set mortar and taped with a 51-mm (2-in.) alkali-resistant fiberglass mesh tape. Special attention should be paid to lippage between the CBU's edges, which should match up in height and transition smoothly.

Plumb and flat wall

It is difficult to achieve a plumb CBU substrate with a surface variation no greater than 6 mm over 3 m (0.25 in. over 10 ft). This is one of the trade-offs between CBUs and SBCs. Installers often try to flatten the surface by applying a polymer- or latex-modified thin-set in low areas, but its usefulness is limited (not to mention labor intensive). It is less of an issue with irregularly sized stone or brick where the A/E expects such a finish.

Thin-set adhering

Adhesion to the substrate—be it SBC or CBU—is just as important as it is to the veneer's back. Rarely do cohesion failures occur in the thin-set adhesive—problems usually result when one side fails to adhere. Both the substrate and veneer have to be clean and free of contaminates, which could act as bond-breakers. The adhesive has to come into full contact with both surfaces. It is recommended to forcefully scrape a thin coat of the thin-set to both surfaces during the installation process, making sure it remains tacky when the thin-set for setting is applied.

Per ANSI, there can be no less than 95 percent coverage on the tile's back. Furthermore, voids should be avoided, as they can lead to pockets that collect moisture, which leads to efflorescence or expansion problems in colder regions. Since most current installations go employ larger tiles and stone modules, it is critical to ensure enough thin-set is applied. Air trapped in the back as the tile is placed has no way of escaping.

NTCA recommends troweling the thin-set in one direction, then setting and moving the tile perpendicular to that direction to let air escape. Large stone tiles require applying a substantial amount of thin-set to both surfaces and setting, which may require pulling pieces off during the process to ensure full coverage.

Figure 3 (previous page) depicts an installer who used a big 19-mm (0.75-in.) marble loop trowel to apply thin-set to the wall, but it was not enough to compensate for the crooked wall. The tile—whose back had no contact—was being held by grout alone. This is where a QC plan works to ensure tiles are getting full coverage.

A third-party inspector should randomly pull freshly set tiles for inspection (this way, they can be reused with minimum effort). When one tile pulled from an area does not have full coverage, three more are subsequently pulled. Likewise, when one or more does not have full coverage, then the entire section of work should be removed and replaced.

Another potential problem is having the thin-set dry before it achieves an adequate bond. This can be caused by a number of things, including hot and windy weather, a highly absorptive tile/substrate, and applying the thin-set too soon, thereby letting it form a non-adhesive skin. Product limitations must be noted and provisions made for protection and adjustments. Cover must be provided for the installation as needed during high/low temperatures, and to act as a rainscreen.

Thin-set adhesive

The adhesive must withstand a shearing stress of 344 kPa (50 psi). However, when one considers the various potential

Additional Information

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01450–Quality Control Requirements
04400–Stone
09380–Modular Stone Tile
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Uniform Building Code

Abstract

Quality control is key to the success of ceramic tile, stone, and thin brick exterior facade installations. Suitable products, adequate substrates, proper preparation, and most importantly, a thorough and complete specification, are the elements needed to ensure a successful installation. This article covers the adhesion methods for installing ceramic tile, stone and thin brick, pointing out areas requiring special attention, particularly with regard to scratch-and-brown coats (SBCs) and cementitious backer units (CBUs).

problems with uncontrollable climatic conditions, imperfect job site conditions, and the labor force, it becomes clear why the best available products should be used, not just those meeting minimum requirements.

CTIOA recommends a polymer- or latex-modified thin-set for exterior veneers meeting a minimum of 2.2 MPa (325 psi) shear bond strength to porcelain tile (per ANSI A 118-4-1999, *Ceramic Tile* [F-5-2-4]). Porcelain tile is the standard because it is very dense and impervious, making it one of the most difficult materials to bond. Modified thin-sets come in various levels of quality, which is why CTIOA calls out the performance level. Quality modified thin-sets provide better adhesion, tack, open time, and other performance characteristics, which help prevent some of the aforementioned problems.

Grouting tile joints

On larger dimension stone installations, a sealant should be used to fill joints between units, as this keeps moisture from penetrating grout joints. Otherwise, the grout should be a lower absorbing and better-adhering polymer-modified grout, or a latex-modified grout meeting ANSI A 118.7, *Polymer Modified Cement Grouts for Tile Installation.* Porous veneers should be sealed prior to grouting to aid in clean-up, but edges have to remain unsealed. Regardless of whether the grout is bagged and tooled, or troweled in the joint, it needs to be well-compacted and shaped to facilitate drainage and prevent any moisture collection. One should seal the clean tile and grout surface after the installation for maximum protection.

Conclusion

Ceramic tile, natural stone and thin brick exterior veneers can be very durable and long-lasting installations when specified/installed clearly and correctly. The QC plan should not be left up to the subcontractor to implement; instead, a third party should be assigned.

As in all things, trade-offs are involved with ceramic tile, thin brick, and natural stone veneers. However, when one specifies any of the legitimate installation methods correctly (and provides adequate quality controls), the resulting work could conceivably last centuries, making a statement of design and quality integrity for generations to come.