Hoffmann Architects

Journal of architectural technology published by Hoffmann Architects, specialists in exterior rehabilitation

JOURNAL

Third Issue 1997 Volume 15 Number 3

Thin-Stone Veneers Offer Unique Design and Performance Demands

Theodore F. Babbitt, AIA

New stone-cutting technologies have allowed for ever-thinner stone veneers to be used as a curtain-wall component on high-rise and other buildings, a radical departure from the traditional use of dimension stone as a load-bearing element or a heavy-weight, non-load bearing facade. But while these veneers offer an excellent design opportunity at a cost lower than dimension stone, relatively little data is available on their long-term performance. And problems are starting to crop up after just two decades of use. Owners, architects, and builders should be forewarned when choosing thin-stone veneers: precise detailing is essential to prevent displacement, cracking, spalling, water intrusion, and, ultimately, failure.

Thin-stone veneers are commonly defined as dimension stone cut to thicknesses of 2" or less (dimension stone is typically more than 2" thick). As with dimension stone, veneers are available in granite, limestone, marble, sandstone, slate, and travertine. A relatively new product known as reinforced stone veneer is also available. Made of very thin stone veneers laminated with epoxy to a reinforcing expanded-steel mesh, these reinforced stone panels come in 5/16" and 3/16" thicknesses and offer the strength of stone veneers twice their thickness. This new technology was developed in Turin, Italy and to date has been used in Europe and New York City.

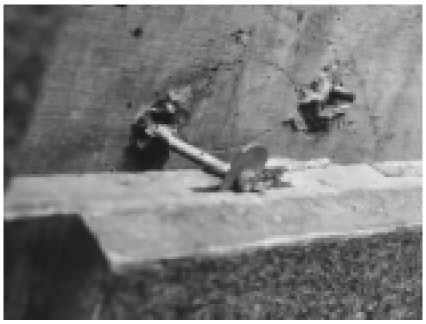
Mr. Babbitt is an expert with more than 45 years of experience in design and technical issues for exterior rehabilitation. As Director of Architectural Services, he oversees stone, curtain wall, and roof rehabilitation services for Hoffmann Architects.

Thin-stone veneer being prepared for face-pinning.

An Intrinsic Danger

While the engineering principles and physical properties of dimension stone are well understood and tested by time, thin-stone veneers offer a new realm of design, engineering, fabrication, transport, and installation demands. Testing prior to installation may show no problems, but under real-world conditions, veneers may begin to display unexpected and serious potential for failure. Actual failure has occurred in many cases.

The very thinness which makes veneers so economically attractive is also the instrument of their downfall. That is because stone's relative thickness has a direct effect on its performance. Thin veneers suffer more than dimension stone — and perform differently — under the onslaught of thermal movement, gravity, wind, seismic, and handling loads, and with the settlement of surrounding building materials. Veneers are also more subject to wear from environmental conditions. Even the building interior becomes more



An anchor set in a slot in the top of a thin-stone panel.

prone to moisture damage when a thin-stone cladding is used. There is simply that much less between the building interior and the elements. Dimension stone is also far better able to handle the wide variances in tolerances of companion building materials. The connections between panels require new and complex techniques. Maintenance demands are more critical. All of which requires expert knowledge on the part of the design and construction team.

Image and Endurance

So why use thin-stone veneers at all? Simply put — aesthetics, performance, and economics. Stone, whether thin or thick, is the hallmark of classical design — timeless, monumental, and enduring. As a design medium, it offers the architect and owner a stellar array of color, texture, and finish choices, and can be used for exterior cladding, interior flooring and walls, and ornamentation. Yet it's not all beauty. Stone provides a stable thermal mass which is energy-efficient, relatively resistant to environmental damage, and easy to maintain. With the advent of thin-stone veneers, all this becomes much more affordable to the building owner, as the lighter weight of the stone will mean savings on structural costs.

Common Problems

The most common source of problems in thin-stone cladding comes from:

- Anchorage failure due to placement of the kerf, slot, or hole too close to the edge of stone. This will cause the stone to break and lead to loss of securement to the back-up structure.
- Anchorage failure due to corrosion, material failure, incorrect installation, or unanticipated shear force (e.g. deflection).
- Anchorage failure due to warping or bending of the stone.
- Cracking and spalling due to insufficient joint width or the use of rigid grout or epoxy where a flexible sealant should have been used. Both situations fail to accommodate thermal or dynamic movement.
- Cracking and spalling due to water infiltration behind the stone, which will also lead to damage to the back-up structure through subsequent freeze-thaw cycles.
- Cracking and spalling due to improper installation, including over-drilling, or micro-cracking caused by dry-sawing and dry-drilling.

These common problem areas, and others, are looked at in more detail below.

Fabrication issues

Stone is essentially a brittle material that will crack, spall, or shatter under stress. How well stone performs over time is as much a question of its interior composition as it is of its intended use. Strength, density, and composition can vary widely, even with the same type of stone. Natural weak points within the stone must be analyzed and addressed in both fabrication and design to reduce the risk of cracking along rift planes. The stone must be cut at the proper angle and to the correct dimension to avoid creating weak points.

Stone texture can also play a role in performance. A thermal finish on granite veneer, for example, reduces its thickness by up to 1/8th of an inch. In turn, that loss can reduce bending strength by up to 30%, increasing the risk of cracking under seismic or wind loads. Thermal finishes also increase the risk of water infiltration, as the dramatic temperature differential created in applying the finish can cause micro-cracking within the crystalline structure of the granite. Those micro-cracks can allow water to penetrate up to 1/4" deep into the stone, leading to cracking and spalling through the stress of freeze-thaw cycles. A similar weakening effect occurs when brown-stone is traumatized by bush-hammering, a type of decorative finish.

Handling and fabrication concerns

Thin-stone veneers are particularly subject to handling damage, which can occur at the quarry, at the panelization

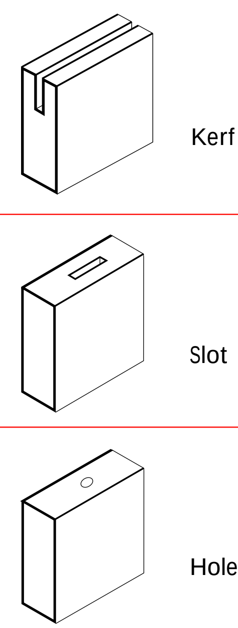


Illustration A: Anchorage Types

or cutting plant, during transport to the job site, or during installation. The risk of cracking increases when the stone is transported flat or when lifted from a horizontal position. Even vehicular vibration can cause damage. Proper packing materials should be used to cushion the stone during transport.

Hysteresis
Most thin-veneer stones remain dimensionally stable, even with thermal expansion and contraction. Some relatively pure, fine-grained marble veneers with uniform texture, however, may gradually expand with each thermal change, a condition know as hysteresis. This "growth" occurs in minuscule increments, which nonetheless add up over time, causing the veneer to cup or warp. That in turn increases the stress on both the anchorage system which holds the veneer in place and on the supporting structure. If analysis of the selected stone panel shows a propensity to hysteresis, specifying a thicker panel can help mitigate its effects.

Design and Installation Issues

There are three basic installation systems used in thin-stone cladding:

1. Hand-set stone with mortar joints and anchors that connect to the structure. This system is more typical of thicker dimension stone systems, and more likely to be found with a concrete or masonry back-up structure.

2. Hand-set stone with sealant joints and anchors that connect to the structure. This system is an adaptation of the above system and is commonly found on steel-framed buildings.

3. Prefabricated panels with steel frame, steel truss, or precast concrete back-up. This method is often used on high-rise buildings, as the panels can be installed from the interior. These panels frequently serve as spandrels or in-fill panels on curtain walls. The stone is attached to the back-up (the structure of the panel) using stainless steel pins set in epoxy.

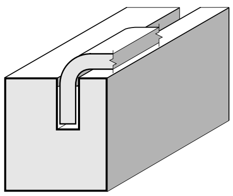
When a pre-cast concrete back-up is used, the pins can be set in the stone, with the concrete then cast against the stone to create a monolithic panel. For aesthetic reasons, "false" joints are often created between stones that are attached to the same panel. In most situations, the panels span one structural bay, and are secured at the column lines to allow the columns to directly carry the gravity load.

Less commonly used are stone panels "glazed" directly into mullions (such as the technology from Turin, Italy described earlier) or exterior stone tile set with tile techniques. The latter is not recommended due to its lack of durability.

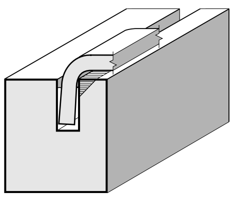
Anchorage
Anchors connect the thin stone to the structure of the building — the steel or concrete spandrels and columns which are the ultimate support of any facade. Choosing the right anchorage is vital to the performance of thin-stone veneers. Adhesives alone are not enough to secure the stone to the building. Even in the case of panelized stone, the pins create a positive mechanical anchorage to the back-up panel. In general, anchors should be made of stainless steel to avoid corrosive interaction with any metallic elements that may be present in the stone.

There are two types of anchors used with thin-stone veneers: anchors which are inserted into *kerfs* and anchors which are inserted into holes drilled into the sides or rear of the stone panel. (A kerf is a narrow slot cut longitudinally into the edge of the stone panel, and is used to hold an anchor which secures the stone slab to its support backing. Illustration A on

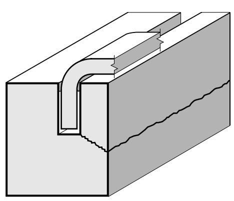
A pull-test in the back-up wall is used to evaluate anchorage performance.



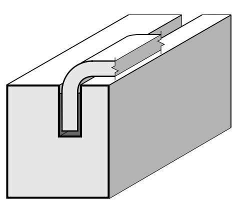
B.1.
Anchor slot has filled with water.



B.2.
Anchor is binding on edge of slot.



B.3.
Incorrect slot placement leads to breakage.



B.4.
Mortar in slot prevents water intrusion and binding. Sealant is used in some designs.

Illustration B: Anchorage Design

page 2 shows an example of a kerf.)

Both kerfs and holes should be pre-sawn and pre-drilled as part of shop fabrication. The kerf's depth is vital — deep enough to hold the anchor but shallow enough to avoid weakening the stone during fabrication. Pre-drilled holes should have a diameter of not more than one-fourth of the stone's thickness, and the anchor should be placed in the center-third of the stone's thickness. A common failure problem is breakage at the inboard side of the kerf, as shown in Illustration B.2. on this page.

During fabrication, kerfs are often dry-sawn or dry-drilled. The thermal differences between the drilled area and surrounding stone during this work can cause minute fractures in the kerf. If cleavage planes are present, this cracking can travel far beyond the drilled area. The result is a significant loss in the veneer's bending strength, increasing its vulnerability to dynamic loads.

When using hand-set thin stone, anchors are set into holes, slots, or kerfs. Relieving angles can be incorporated into the overall anchoring scheme, as they provide positive gravity-load support at each floor level. In some situations, a small block of stone is pinned and epoxied to the back of a thin-stone slab and allowed to rest on the relieving angle to support the stone.

Environmental risks and water control

Surface damage to the stone isn't the only result of freeze-thaw cycles and acid rains. These and other environmental factors also pose a serious risk to the stone's flexural strength due to the weakened bonds between mineral particles in the stone. Hoffmann Architects recommends that a flexural strength test be conducted twice on the selected stone veneer: once after fabrication and once after the veneer is subjected to the "accelerated aging" test recommended by ASTM.

Wind-driven rain and condensation will inevitably cause some water penetration into the veneer. Flashings and weepholes should be specifically detailed to give this moisture a direct route to the outside.

Kerfs must also be carefully designed and fabricated to avoid pooling of water. This is a particularly common problem area, where a poorly cut kerf will increase the chance for water absorption into the stone. (Please see Illustration B.1. on this page.) Elastomeric sealants or caulks compatible with stone should be used to keep moisture out of the kerf. Mortars and expanding mortars should not be used, as they will crack and fail under thermal stress.

Accommodating movement

Thermal movement can have a dramatic and negative effect on thin-stone veneers, particularly on the anchorage system. Because the stone, anchorage system, and support structure each experience different degrees of movement during normal thermal change, or from seismic or wind loading, enormous stress is placed on the anchorage system. The anchorage system design must anticipate and accommodate these diverse rates of change.

Horizontal expansion joints should be placed along the horizontal gap between the stone panels and beneath any supporting anchors or relieving angles. This will help minimize the stress of vertical movement between the veneer and the support structure, especially the shrinkage movement common to concrete structures.

In turn, vertical expansion joints will accommodate the effects of any horizontal movement of the stone caused by thermal change or by deflection of the building frame.

As a general precaution, anchorage should not be over-restrictive. If anchors are mortared, grouted, or epoxied, then movement must be addressed and allowed for elsewhere in the curtain wall design. Conversely, anchors that are loose or set in sealant must not be too permissive of random movements, such as those caused by wind gusts hitting the stone. This dichotomy is a critical design issue, and a careful balance between the two must be achieved.

Remediation Strategies

One primary maintenance rule in thin-stone veneers is the full replacement of all joint sealant every 15 to 20 years. Mortar joints, if present, should be re-pointed as needed, usually every 20 to 25 years.

Patching may be required for a specific crack, break, or spall in the stone. (Please see the related article, *"Face-pinning Stone Veneers,"* on page this page.) One repair technique, known as a "dutchman repair," calls for sawing out the damaged area of the stone, inserting a new, custom-fit slab into the opening, and securing it with epoxy and steel pins. It is a more expensive solution than patching, but may be necessary for large repair areas. Matching the appearance of new and existing stone is difficult, however.

Face-pinning can be used to re-secure a cracked piece of stone which is in danger of breaking loose or an entire piece of stone which has suffered anchorage failure. While this repair technique may mar the appearance of the stone, it is often undertaken as an essential safety measure. More extensive repair projects may involve removing and re-setting the stone or installing a replacement stone. Re-setting stone is often impractical,
(continued on page 8)

Face-pinning Stone Veneers

Face-pinning of thin-stone veneers is a remedial strategy most often undertaken as a safety measure to prevent loose, displaced, or cracked stone from falling. The following steps are recommended for face-pinning:

Identifying the need
Anchors should be installed wherever stones are cracked or dislodged. The architectural elevations should designate which stones are to be pinned.

Preparing the stone
A counterbore hole approximately 1" in diameter by 3/4" deep should be drilled in the stone to accommodate the nut and washers. A 3/8"-diameter corresponding hole should be drilled in the concrete or masonry back-up to hold the anchor rod. A depth gauge used during drilling will ensure the proper depth of both openings. If the stone is less than 2" thick, however, counter-boring may not be possible, and the nut will remain exposed, a definite aesthetic disadvantage.

Preparing for installation
When using an *adhesive anchoring system,* the holes in the back-up structure are cleaned first of dust and stone fragments (using a brush and compressed air) before the adhesive is injected or inserted. This will help achieve a solid bond between the adhesive and the anchor rod. The anchor rod should be left undisturbed during the setting time specified by the adhesive manufacturer. Once the adhesive has set, a stainless steel washer and nut should be installed over a neoprene pad.

When using an *expansion anchoring system,* a syringe is used to remove

Face-pinning

Step 1: Drilling the stone and back-up wall in preparation for the anchor.

Step 2: Injecting the epoxy adhesive into the anchorage hole.

Step 3: Inserting the anchor rod with nut.

drilling dust from the hole. The anchor should be pre-assembled, using two neoprene pads and a stainless steel washer, with the nut engaging two or three threads of the anchor rod. The anchor should be set to its full depth with light hammer blows. The anchor is then tightened to the specified torque, using a calibrated torque wrench, causing the expansion shield to grip.

Once the anchorage is in place, a patching material is applied to the counterbore hole over the nut and rod. For limestone and marble, Hoffmann Architects recommends the European-made JAHN materials. These come in a variety of colors which can be custom-blended for an exact match.

Patching granite requires a slightly more complex approach, primarily because of the difficulties in matching the patch material to the original stone. Typically, the architect determines the number of samples needed to conduct an accurate color review, which is done prior to the actual patching. The color testing is done using an Akemi epoxy (with a coloring paste kit), iron oxide pigments, and granite chips that are similar in appearance to the original granite. The samples of epoxy patching material are prepared for the owner's review, using the coloring paste in some samples and the iron oxide pigments in others, and adding in granite chips as needed to improve the color match.

The patching surfaces must be dry and free of grease and dust, with smooth surfaces roughened first to improve bonding. Once the patch has been applied and hardened, it can be polished to match the surrounding surfaces.

This process is also used in other granite patching situations that are unrelated to face pinning, such as the repair of cracks and spalls. ■

The Facility Manager's Bookshelf: **Thin-Stone Facades**

A. Periodicals

1. *Dimenionsal Stone* (monthly). Subscriptions: $50/year. Dimensional Stone Magazine, 6300 Variel Avenue, Suite I, Woodland Hills, CA 91367. 818-704-5555.

2. *Building Stone Magazine* (quarterly). Subscriptions: $65/year. Building Stone Institute, P.O. Box 507, Purdys, New York 10578. 914-232-5725.

3. *Stone World* (monthly). Subscriptions: $65/year. Stone World, 299 Market Street, Third Floor, Saddle Brook, New Jersey 07663. 847-291-5224, fax 847-291-4816.

4. *Journal of Performance of Constructed Facilities* (quarterly). Subscriptions: $76/year for non-members. American Society of Civil Engineers, Technical Council on Forensic Engineering, 345 East 47th Street, New York, NY 10017-2398.

5. *ENR: Engineering News-Record* (weekly). Subscriptions: $74/year. The McGraw-Hill Companies, Fulfilment Manager, ENR, P.O. Box 518, Hightstown, New Jersey 08520. 800-525-5003.

B. Technical Articles from *The Construction Specifier*

To order reprints, contact the Construction Specifications Institute at (800) 689-2900. Reprints are $4.00 each, $10.00 minimum order.

1. Algeo, Harold. "What the Specification Writer Needs from the Stone Industry." *The Construction Specifier,* April 1961, p. 41.

2. Hoigard, K. R. and Raths, C. H. "Specifying Stone Testing." *The Construction Specifier,* December 1991, p. 108.

3. Hurd, Robert. "Commercial Uses for Marble." *The Construction Specifier,* August 1986, p. 76.

4. Pritsker, Ellen. "Coloring the Skyline with Granite." *The Construction Specifier,* February 1985, p. 40.

C. Technical Articles - Miscellaneous

1. Dorris, Virginia Kent. "Anchoring Thin-Stone Veneers." *Architecture,* December 1993, p. 105-107.

2. Grassi, Ennio. "Stone Materials in Curtain Walls: Design Criteria, Technical Performance, Use of Stone in Pre-fabricated Systems." Booklet published by Internazionale Marmi E Macchine Carrara S.P.A., Ente Minerario Sardo for the Italian Marble Council, December 1992. Distributed by Italian Marble Centre, London.

3. "Shop Drawing Process of Stone Veneered Cladding Systems." *Journal of Architectural Engineering,* June 1997.

Compiled by Alan P. Eddy, Technical Information Specialist ■

REPRESENTATIVE PROJECTS

Rehabilitation of Thin-Stone Veneers

Resolving deterioration and failure problems in thin-stone veneer cladding requires extensive investigative work into the underlying causes of the problems. Hoffmann Architects begins each rehabilitation project with an exhaustive study of existing conditions, original contract documents, and other historical data on the building. From there, the firm's team of architects and engineers begin to formulate repair strategies that address those root causes. The final rehabilitation recommendations reflect both the technical and aesthetic requirements of the project, budgetary and facility life-cycle considerations, and occupancy needs during construction.

Once the repair method has been selected, the firm prepares comprehensive plans and specifications for competitive bidding. On-site project staff and contract administrators track the progress and quality of the work throughout the project.

Hoffmann Architects has been called in by major corporations, private institutions, and real estate owners to provide specialized consulting on the rehabilitation of thin-stone facades. The following is a sampling of the firm's work in this field:

Pfizer, Inc.
World Headquarters
New York, New York
(Pfizer, Inc.)

Rockefeller Center
Lower Plaza and Skating Rink Area
New York, New York
(Rockefeller Center Management Corporation)

The Philip Morris Building, 120 Park Avenue, New York, New York.

Building # 76
Hoffmann-La Roche
Nutley, New Jersey
(Hoffmann-La Roche)

The Chase Manhattan Bank, N.A.
New Rochelle, New York
(The Chase Manhattan Bank, N.A.)

110 South Bedford Road
White Plains, New York
(Edward S. Gordon Company, Inc.)

Lincoln Center for the Performing Arts, Inc.
Avery Fisher Hall
New York, New York
(Lincoln Center for the Performing Arts, Inc.)

One Magnificent Mile
Chicago, Illinois
(Teachers Insurance and Annuity Association)

The Executive Building
Washington, District of Columbia
(Prudential Insurance Company)

28 State Street
New York, New York
(Prudential Insurance Company)

335 Madison Avenue
New York, New York
(Cushman & Wakefield, Inc.)

1251 Avenue of the Americas
New York, New York
(Rockefeller Center Management Corporation)

American Express Company
200 Vesey Street
New York, New York
(American Express Company) ■

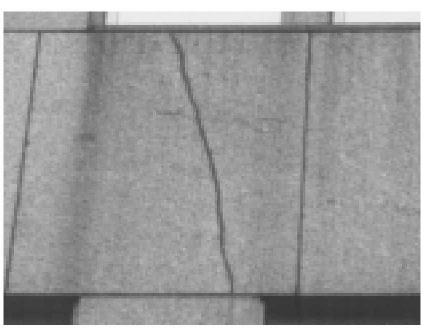
Bristol-Myers Squibb Company, Wallingford, Connecticut.

however, as breakage frequently occurs during removal.

Another key maintenance and repair consideration is at flashings and weeps.

A worker removes failed patching material from a crack in the limestone facade.

Damaged stone has been removed, exposing the concrete back-up wall.



A crack in the granite facade.

Any water trapped within the wall is guaranteed to cause trouble — including freeze-thaw damage, corrosion, efflorescence, and many other problems. Prevention is the best solution. Check for clogged weep holes during routine inspections and be sure to include flashing repairs in any remedial work.

Conclusion

All told, thin-stone veneers can offer enormous design and image opportunities to owners at a more affordable cost than traditional dimension stone. Avoiding the pitfalls of this relatively new technology is the challenge. The owner's best bet is to work with qualified architects and engineers who have an in-depth understanding of the quirks and demands of thin-stone design. ■

JOURNAL is a publication of Hoffmann Architects, specialists in investigative and rehabilitative architecture/engineering services, including the analysis and resolution of problems within roofs, exterior walls, glazing, and structural systems of existing buildings, plazas, and parking garages.

Please send news, technical information, address changes, or requests for free subscriptions to Emily D. Dowden, Editor, Hoffmann Architects, 432 Washington Avenue, North Haven, Connecticut 06473.

For more information on the technical issues discussed in this issue or on the specific services we offer, please call Brian Schafer at (203) 239-6660.

Editor: Emily D. Dowden
Graphic Services: Bligh Graphics
Editorial Services: Jonelle Lawhorn Hobbs Communications

Hoffmann Architects
432 Washington Avenue
North Haven, Connecticut 06473
(203) 239-6660

FORWARDING AND ADDRESS CORRECTION REQUESTED