ISSUE 1/2005 ■ VOLUME 22 ■ NUMBER 1

Hoffmann Architects

Journal of architectural technology published by Hoffmann Architects, Inc., specialists in the rehabilitation of building exteriors.

Journal

Repair and Maintenance of Historic Marble and Limestone Structures

Regular Maintenance Key to Longevity

Arthur L. Sanders, AIA and Lawrence E. Keenan, AIA, PE

Whether you're thumbing through the pages of a history book or surfing the web, it's easy to see that stone is a lasting testament to architecture through the ages.

Inappropriately applied sealant is failing, or missing altogether, in joints. Areas of the sculpture are beginning to show signs of erosion.

One of the more enduring building materials, stone has been used throughout history for building construction. In particular, marble and limestone are two of the most commonly encountered materials in historic structures. For thousands of years, these materials have been valued for their beauty and versatility.

Despite their aura of permanence, both limestone and marble can suffer from time and wear. As a result of today's increasing urbanization and pollution, stone deterioration is occurring far more rapidly than in the past. Dirt accumulation, cracked masonry, spalling and loss of structural integrity are among the problems affecting stone structures.

Origin of Limestone and Marble

Limestone is a broad term that refers to many types of sedimentary rock in which calcium carbonate is the major constituent. One hundred million to 500 million years old, limestone is derived from fossil deposits of marine animals. It generally has a uniform

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consistency and texture and is usually buff or off-white in color, but it can also be gray or very light in tone. Marble is primarily a metamorphic form of limestone, transformed under intense heat and pressure into a hardened mass of calcium carbonate. In general, marble has a much finer texture than limestone, which allows it to be polished. Limestone cannot be polished.

Importance of Repairing Historic Marble and Limestone

A building's exterior provides protection from the elements and conveys its historic character. The age, style and significance of a building or structure can often be understood by analyzing exterior designs, features and materials. Changes in taste, fashion, architectural style and use may be evident. In any rehabilitation project, it is critical to treat the exterior with great care.

Distinctive features, finishes and construction techniques are examples of craftsmanship that characterize a property and should be maintained. If possible, deteriorated historic features should be repaired. If replacement is necessary, the new feature should match the old as much as possible in design, color, texture and other visual qualities.

Where to Start?

The first step in the rehabilitation of stone at a building's exterior involves the accurate assessment of that building's existing system. In other words, before you can know how to fix something, you have to know how it was intended to work in the first place. Then a proper scope of rehabilitative work can be established.

As water is the primary cause of deterioration, understanding the management of water in the façade is absolutely essential. Mass wall systems must be allowed to breathe, cavity wall systems must drain, and barrier wall systems must be sealed. Repairs for each can be drastically different. The interaction of building components (roof, parapets, windows, doors, etc.) must also be understood.

What Is the Condition Of Your Building?

A thorough assessment of your building's exterior condition is the next step in the development of the scope of required work for a successful stone rehabilitation program. Identification of problem conditions early in the process is less costly by far than "righting" wrongs after your project has been completed. That condition assessment should include:

1. Identification and/or classification of existing materials;

2. Evaluation of existing façade systems including drainage, insulation, vapor barriers and structural supports;

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Large spall is shown in limestone panel above window

Removal of spall exposes corroded steel beam behind stone panel.

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3. Thorough inspection of all elements documenting all signs of deterioration and defects;

4. Investigation of hidden conditions through probes into exterior building components;

5. Investigation of material deterioration through field and laboratory testing methods; and

6. Identification of potentially hazardous and/or unsafe conditions.

The subsequent development of a realistic budget and project schedule, and the preparation of appropriate design documentation, materials and systems specifications, will ensure that a good stone rehabilitation program can be executed.

A worker scrubs and removes softened soil from the water-soaked limestone façade.

In For a Penny, In For a Pound

Proper repair of stone façade elements can seem costly. However, this cost can easily be eclipsed by the cost of correcting deferred repairs or ignored defects. Repairs that only address problems on the surface can mask deeper issues and often allow deterioration to continue unnoticed. In the long run, cost-effective repairs always correct the root problem first before restoring the damaged finish material.

It would be difficult to justify repairing a water-damaged ceiling below a leaking roof without first repairing the leaky roof. However, this type of repair happens with façades more often that you'd think. It's important to understand the nature of the problem and the methods necessary to repair the defect. Be wary of solutions that don't completely address the problem.

Removing a large piece of stone on the side of a façade any number of stories above the ground may seem daunting, but this might be the only way to access the defective condition. Specially trained design professionals and contractors are necessary to undertake such work.

Consider, for example, that a property manager discovers a crack at the base of a stone panel on a building façade (see photos on page 2).

Proper repair of the condition should start with removing enough of the stone to identify the root cause. Repairs could consist of removing all the spalled stone, preparing and painting the embedded steel and then repairing the stone with either a dutchman or patching mortar to match the existing stone. If, however, prior to identification of the root cause of the stone spall (in this case, the rusted steel embedded in the wall), the crack and adjacent joints are sealed with patching mortar or caulking compound, water would still continue to enter the stone. The embedded steel would continue to rust and expand, displacing the patched stone once again.

Sources of Deterioration In Stone

There are many sources of stone deterioration. Damage occurs through weathering, the invasive action of plant growth, pollution, and dirt accumulation. Further damage can occur through erosion, as a result of movement in stone (thermal expansion/contraction), faulty or broken anchors, and even human error in design, engineering or construction.

Because marble and limestone are carbonates, both stones present

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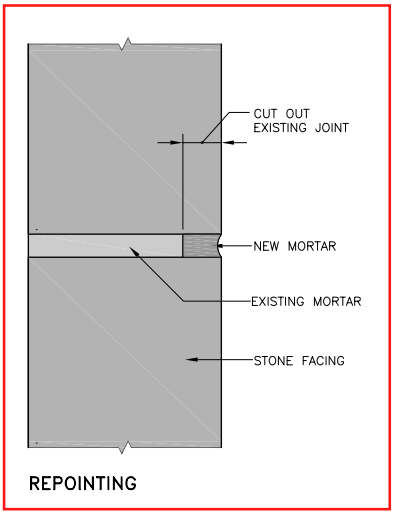

Figure 1

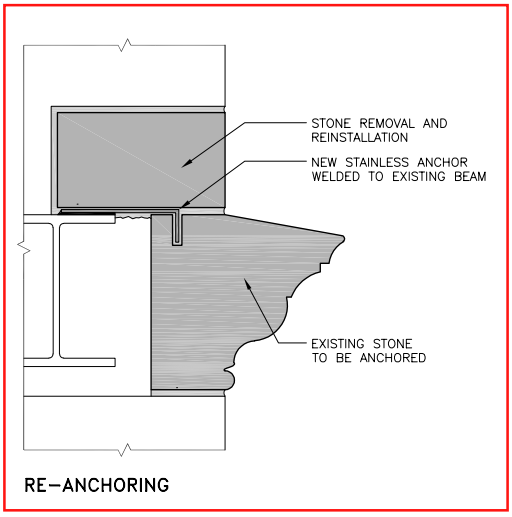

Figure 2

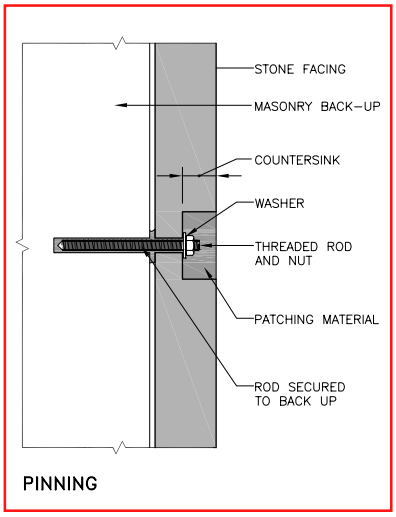

Figure 3

(continued from page 3)

several key maintenance and preservation problems, for example:

1. Unlike granite, marble and limestone are highly sensitive to and soluble in acid (think baking soda and vinegar). The natural acidity of rainfall – even without the compounded effects of acid rain, automobile exhaust and other airborne pollutants – will cause the stones to deteriorate over time.

2. Marble and limestone are porous and absorb water readily. The rate of absorption and the level of porosity vary. Water trapped within the stone will exacerbate deterioration. Therefore, it is important to ensure that moisture infiltrating the stone can evaporate.

3. Marble and limestone are relatively soft stones and can be easily scratched and marred. This softness means chemical cleaners, sandblasting and wind-driven grit will take their destructive toll.

The chart on page 6 shows some common defects and possible causes of damage. The underlying causes, as well as the indicators themselves, should be thoroughly investigated before any rehabilitative work is performed. There is no value, for example, in patching a cracked marble wall panel if the cause for the crack lies *behind* the panel at its anchorage system.

Common Repair Techniques

Cracked, spalled or exfoliated limestone and marble should be repaired in a timely manner to prevent further damage. Typical repair methods include the following:

Repointing requires cutting out failed joint mortar and applying new mortar that is finished to replicate the original mortar style. There are two important points to take into consideration when repointing: the new mortar should be of a weaker compressive strength than the surrounding masonry to avoid spalls at the joints, and joint sealant is not recommended, as it prevents the migration of damaging moisture from within the wall system. (Figure 1)

Re-anchoring is usually necessary when movement of the stone from its original position has broken existing anchors or fractured the back of the stone. (Figure 2)

Pinning stonework is performed by securing non-corrosive rods through the stone into the masonry backing. (Figure 3)

Patching is used to repair small areas of damaged stone with a matching cementitious material that is applied and built up in layers until it matches the original profile. For larger patches, pins might be needed to secure the new material.

Sculpting is the process of re-carving badly eroded stone or re-accentuating indistinct detailing. This method is frequently employed to repair ornamentation.

Resetting returns displaced stone to its original position.

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Stone replacement can be the most viable approach for restoring large areas of damage. A new anchoring system may be required.

Crack repair can be accomplished by injecting an adhesive material into the fissure to provide water impermeability and prevent further cracking. A minor crack can be successfully repaired by routing the crack and filling it with patching material.

Consolidation is a time-tested technique of reconstituting softened or deteriorated stone by filling the voids and binding the grains within the stone. Consolidation has many applications for the preservation of historic structures, but requires thorough testing and evaluation to ensure that the consolidant leaves a compatible vapor-permeable surface. (Figures 4a and 4b)

A Word About "Protective" Coatings

Waterproof coatings should rarely, if ever, be used on stone. Although these coatings prevent water infiltration, they have a tendency to trap moisture within the stone and the masonry in general. Even water-repellent sealers will prevent the natural migration of water from stone and should be used with great caution, if at all.

Ongoing Maintenance And Cleaning

Ongoing maintenance is essential to preserve exterior stone surfaces and to prevent future deterioration. A good maintenance program includes routine inspections to detect early

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Figure 4a

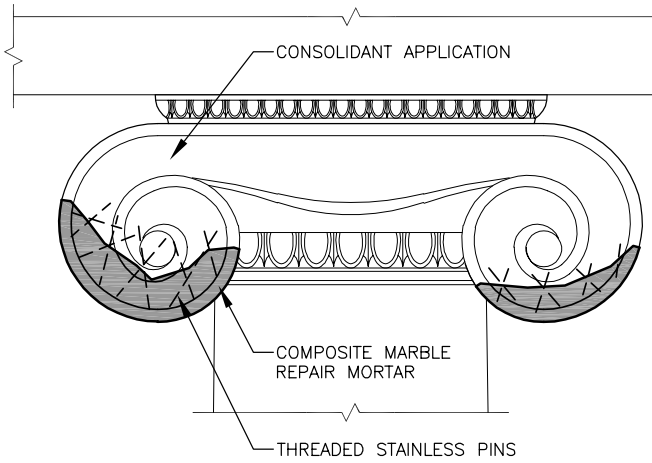

Figure 4b

Erosion of volute face of marble column capital exposed to weather (Figure 4a). The illustration demonstrates consolidation methods used to repair the damaged area (Figure 4b).

Common Marble and Limestone Problems

Conditions	Description	Probable Causes
Open Joints	Loose, broken mortar	Result of poor mortar bond, building movement, aging and water intrusion.
Crumbling or Sugaring	Brittle or broken stone; loose granules	Typically caused by the binder material being dissolved or weakened through the intrusion of water.
Gypsum Encrustation	Hard, gray surficial deposits	Reaction of sulphates in pollution with carbonates in stone. Creates impermeable surface.
Efflorescence	Hazy, white blotching or crystalline deposits on stone surface	Naturally occurring salts within mortar and masonry materials that are dissolved and deposited on the surface.
Erosion	Worn edges or surfaces	Natural wearing away of the stone through weathering and chemical degradation.
Cracking	Narrow, irregular fissures in stone surface	Movement within the façade from expansion, contraction, settlement or other issues. Longer or wider cracks may be evidence of structural flaws.
Spalling	Fracture and loss of surface lamination	Caused by trapped moisture or crystallized salts, corrosion of embedded steel or iron, freeze-thaw cycles or joint mortars that do not allow for natural expansion and contraction.
Grime, Organic Growth, Black Crust	Dark patches, stains, discoloration	Accumulation of waterborne and airborne dirt and pollutants or lichen and algae. Some lichen secrete organic acids that eat away at the stone.
Structural System Flaws	Surface evidence of these hidden problems may include cracking and displaced stone pieces	Causes include improper design or installation, inappropriate mortars and insufficient or incorrect anchoring systems.

representative projects

Marble and Limestone Rehabilitation

These representative projects included marble and limestone rehabilitation.

One Wall Street
New York, New York
Limestone Façade Rehabilitation

U.S. Bureau of Engraving and Printing
Washington, D.C.
Limestone Façade Restoration

New Haven Courthouse
New Haven, Connecticut
Marble Repair and Renovations

Taft Apartments
New Haven, Connecticut
Limestone Façade Rehabilitation

New York Stock Exchange
New York, New York
Marble Façade Restoration

Hoffmann-La Roche, Building 76
Nutley, New Jersey
Marble Panel Rehabilitation

Verizon Headquarters
1095 Avenue of the Americas
New York, New York
Marble Panel Rehabilitation

310 Orange Street
New Haven, Connecticut
Limestone Façade Rehabilitation

Hartford Insurance Headquarters
Hartford, Connecticut
Limestone Façade Restoration

Columbia University Butler Library
New York, New York
Limestone Façade Renovation

Church of Scientology
New York, New York
Limestone Façade Rehabilitation

Cannon House Office Building
Washington, D.C.
Marble Ballustrade/Stair Rehabilitation

Folger-Shakespeare Library
Washington, D.C.
Marble Rehabilitation

Johns Hopkins University Natatorium
Baltimore, Maryland
Limestone Rehabilitation

Radio City Music Hall
New York, New York
Limestone Façade Rehabilitation

Carnegie Mellon University
Mellon Institute
Pittsburgh, Pennsylvania
Limestone Façade Study

Princeton University Mather Sundial
Princeton, New Jersey
Limestone Survey ■

New York Stock Exchange
New York, New York

U.S. Bureau of Engraving and Printing
Washington, D.C.

Hartford Insurance Headquarters
Hartford, Connecticut

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signs of stone damage and joint failure.

Regular washing keeps dirt and pollutants from accumulating on stone, helping prevent deterioration. You should correctly identify stone before cleaning, because certain cleaning agents and treatments, if improperly applied, may cause or accelerate physical deterioration in stone. For that reason, it's best to use the mildest cleaning method possible to get the job done.

Because marble and limestone are especially sensitive to acid-based cleaners, water washing is usually the best treatment. Washing by bucket and brush is a well-established method of cleaning marble and limestone surfaces. Spraying and misting (soaking) is effective on marble and limestone for removing heavy accumulations of soot or crusts that have a tendency to form in protected areas that are not regularly washed by rain.

A purification system might be needed to eliminate the corrosive effects of impurities in the water. And it goes without saying: the surface you're cleaning should be watertight.

Who Is Qualified To Do the Work?

Walk down any street, in any city, and you'll more than likely see good stone rehabilitation intentions gone bad … stone "rehabilitation" work that has caused more harm than good. At the Acropolis in Athens, Greece, for example, a botched 1930s marble restoration project involved the use of iron clamps that rusted over time, causing the structures to further crack and crumble. The outcome was unfortunate and avoidable.

When it comes to stone rehabilitation, you can count on one thing. What you don't know *will* hurt you. It's essential to work with design professionals and restoration contractors who are knowledgeable, trained and experienced in restoring stone structures and surfaces.

Conclusion

Although deterioration in limestone and marble is inevitable, there are ways to slow the process and prevent serious damage. Routine maintenance and inspections can reveal surface damage, displacement and joint failure that can signify more serious underlying conditions. Early detection and prompt, careful attention are key. ■

JOURNAL is a publication of Hoffmann Architects, Inc., specialists in the rehabilitation of building exteriors. The firm's work includes investigative and rehabilitative architecture and engineering services for the analysis and resolution of problems within roofs, façades, glazing, and structural systems of existing buildings, plazas, terraces and parking garages.

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