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Substitute Materials in Historic Restoration:

When to Consider Alternatives

Richard W. Off, AIA

The choice of whether to use substitutes can be more complex and nuanced than it might first appear. While repairing and salvaging existing materials is generally regarded as the first choice when addressing deterioration in exterior restoration projects, replacing some amount of material is often unavoidable. When replacement becomes necessary, design professionals are confronted with a critical decision: to match existing materials in-kind or to use substitutes.

Historic restoration of this Beaux-Arts tower incorporated both traditional materials and, where necessary, substitutes.

Among preservationists, using in-kind materials is considered preferable with respect to historically significant buildings. Nonetheless, there can be situations where the use of substitutes might be the best choice, resulting from various construction circumstances and design criteria. Although traditional construction materials are time-tested and there are good reasons for their continued use, material technology is ever-evolving, as are the codes, regulations, and industry standards which govern their use. Lest we think this only a modern question, it's important to note that substitute materials are not only used within contemporary restoration projects, but also have been employed in construction for centuries.

Lexicon

An evaluation of material use within exterior restoration projects requires defining common terminologies, as well as distinguishing among terms used as synonyms that may not necessarily mean the same thing.

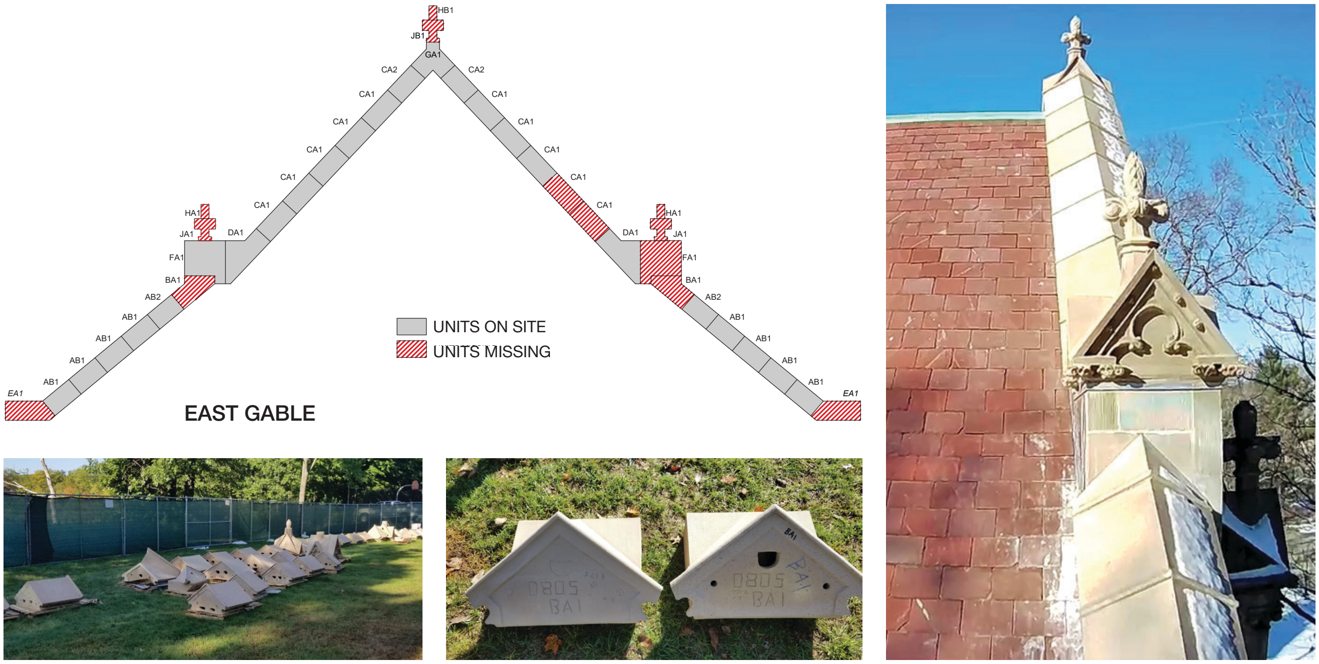
"Substitute" vs "Alternative"

Used interchangeably within the industry, these terms have come to be synonymous. Both refer to a material, product, or system used in place of another. This could involve replacement of select units, comprehensive reconstruction of entire areas and, in some cases, building additions, especially in historic districts. Note that substitutes do not necessarily have to involve more contemporary synthetic materials. Instead, they might also include traditional materials that are more suitable to the application than the original material.

"Existing" vs "Original" vs "Historic"

Although there are instances where all mean the same thing, these terms are not inherently interchangeable. *Existing*

Richard W. Off, AIA, is Senior Architect with Hoffmann Architects + Engineers. With expertise in traditional building and modern materials, he has published and lectured widely on meeting the technical challenges of restoration with historically sensitive design strategies.



Despite the owner's proactive order of replacement terra cotta for deteriorated gables, when units were unpacked and inventoried, some were missing *(left & top)*. Lead times for terra cotta were too long, so polymer-resin composite, carefully matched *(center)*, filled in the gaps *(right)*.

material, which is currently present, may or may not be the same as the *original* material, used when the building was constructed. *Historic,* a more ambiguous term, could imply there is cultural or architectural value to the original building or material, or it might refer to the fact the original construction dated to a certain era or is no longer employed in contemporary practice. These are important distinctions, because replacement always involves *existing* materials but not necessarily *original* or *historic* ones, as the latter two might have already been replaced in a prior project.

"Traditional"

If some original material has been replaced with different materials, the question of which should be matched must also be answered. It is important to note that *historic* does not necessarily mean *traditional* (e.g. stone and wood), as it could reference industrial materials used in 20th century Modernist-style buildings. Furthermore, traditional construction does not necessarily mean the structure is old. The Basilica of Sagrada Familia in Barcelona, Spain, designed by Antoni Gaudí, has been under construction for 140 years, and new stone masonry is still being laid per the architect's original plans. Moreover, thousands of vernacular structures around the world are still built using traditional materials.

"In-Kind"

Matching *in-kind* is often the desired approach when replacing materials, but what in-kind means can be unclear. Does it mean matching material that is original, or, if different, existing? Is it matching general appearance, like size, shape, color, and texture, or physical properties, as per officially recognized standards? Must the material come from the original source, such as a particular quarry or shop, and does it need to be fabricated the same way?

Even where in-kind material is specified, it is critical to understand that not all stone, wood, or metal is created equal. Sourcing, extraction, processing, and classification impact a material's quality. Even if replacement material has the same origins, adjacent existing material may have weathered over time, so it may be impossible to truly match its properties and appearance. These considerations demonstrate the perils of over-reliance on the phrase in-kind without detailed criteria for its project-related meaning and thorough technical specifications that clarify these ambiguities.

"Preservation" vs "Rehabilitation" vs "Restoration" vs "Reconstruction"

Other important terminologies to consider include those officially recognized within *The Secretary of The Interior's Standards for the Treatment of Historic Properties,* established under the National Historic Preservation Act (NHPA). This document defines four different approaches for treating historic properties:

- *Preservation* focuses on the maintenance and repair of existing historic materials and retention of a property's form as it has evolved over time.
- *Rehabilitation* acknowledges the need to alter or add to a historic property to meet continuing or changing uses while retaining the property's historic character.
- *Restoration* depicts a property at a particular period of time in its history, while removing evidence of other periods.
- *Reconstruction* re-creates vanished or non-surviving portions of a property for interpretive purposes.

(National Park Service, "Four Approaches to the Treatment of Historic Properties")

Many projects involve aspects of more than one of these approaches, and the use of substitutes could fall under any of them. However, substitutes are more likely entertained when performing the three latter approaches.

Evaluation/Assessment

Prior to replacing any material, either in-kind or with a substitute, an investigation should be conducted to determine why the material is failing in the first place. Thoroughly assessing the underlying causes of distress allows for appropriate corrective action. The evaluation, which should be performed by a design professional experienced in exterior restoration, may involve investigation techniques such as visual and hands-on inspection, sounding, material sampling and laboratory analysis, exploratory probes, or non-destructive testing. Assessment could also include structural, foundational, seismic, or water intrusion investigations, as the cause of distress might be the result of deficiencies in other areas of the building.

Following the investigation, the existing materials should be evaluated to assess whether they can be repaired and salvaged. Repairs might involve removal and reinstallation or pinning in-situ if the unit is displaced or anchorage has failed, and patching, grouting, or dutchman (partial replacement of the unit's material in-kind) if it is cracked or spalled. Restoration can also include recoating to repair damaged finishes or enhance waterproofing capacity, and cleaning of stains or biological growth. If repairs are insufficient, and the best course of action is replacement for cost, aesthetic, safety, or performance reasons, the design professional should only then consider whether in-kind materials or a substitute should be used.

When to Consider Substitute Materials

One of the foremost reasons a substitute may be used is the limited availability of the original material. Examples include stone from a quarry no longer in service, or old-growth wood that is no longer harvested.

Availability can be an issue even for historic materials which were once mass-produced, such as terra cotta. A popular material in the late 19th and early 20th century that once had many sources throughout the United States, architectural terra cotta now has just two major manufacturers in the country. Limited availability not only affects lead time, as it can take longer to source, but also makes the product more costly.

Asphalt shingles mimicking slate roofing.

Availability can also be affected by the reduced quantity of skilled craftspeople. Prior to mass production, many historic structures with ornamental components were produced by specialized individuals, such as carvers, metalsmiths, stonemasons, and carpenters. Although these trades still exist, most remaining workers within these professions are typically educated to produce more standardized contemporary assemblies. So, there are fewer trained people available to reproduce historic conditions, and this is especially applicable to complex, hand-crafted pieces.

Constructability issues can also generate the need for substitutes, even if the material or trade is readily available. Sometimes, the size, weight, or configuration of original materials might be too cumbersome to replace with a matching material, such as monolithic stone blocks in load-bearing masonry construction. Repair in lieu of replacement of these elements is often preferred.

When material sourcing is a problem, it can be especially concerning when deteriorated material is being replaced to address a safety issue. This is common on urban high-rise buildings, especially those municipalities with stringent facade inspection requirements, such as New York and Chicago. When owners are under pressure to correct safety issues within strict timeframes set forth by local laws, they may be inclined to replace with a substitute, especially if it costs less and is readily available. The problem can be exacerbated by the compounding costs of protection, scaffolding, and stabilization that might be needed to address the unsafe conditions, not to mention the fines incurred from local building departments. These expenses can further sway building owners toward substitutes, at least as a temporary solution.

There can also be performance reasons for selecting a substitute material. A design professional may determine that the original or existing materials have fundamental deficiencies, or they were inappropriately implemented in an assembly, climate, or exposure that makes them prone to deterioration. For example, concealed anchorage and structural systems may need to be replaced with substitutes not only because they lack corrosion-resistance, but also because they may have fatigued or were not engineered to contemporary standards. Sometimes, supporting metal has deteriorated but cannot be replaced. Instead, the design team might replace exterior claddings that rely on these metal components with substitutes that are lighter weight, such as cast composite resin in lieu of stone masonry, or asphalt shingles in place of slate roofing.

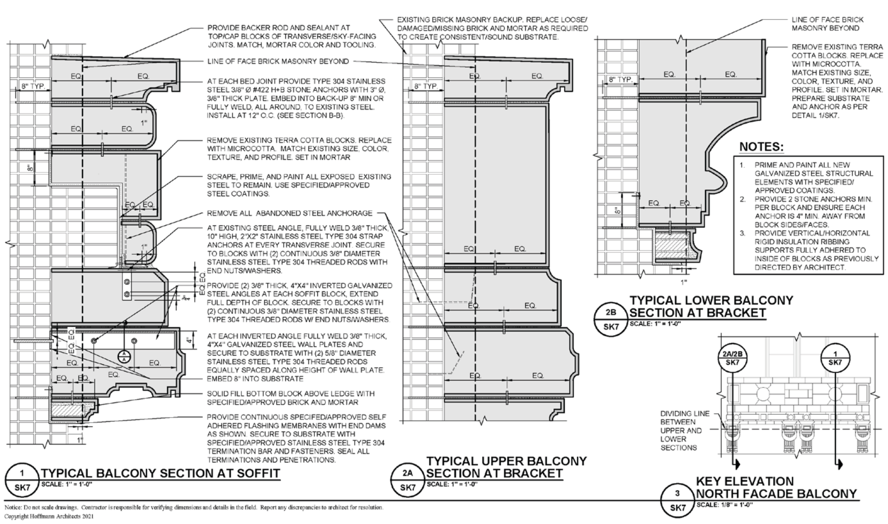
Other backup and underlayment materials that might need to be replaced with substitutes include felt paper and coal tar pitch, historically used as waterproofing. Contemporary advancements, such as self-adhered rubberized or fluid-applied membranes, permit easier and safer installation than these hot-applied materials, and they are more waterproof, too.

Substitutes might also be used when there is a new addition or major reconstruction. For designs intentionally made to look like an intervention to the surrounding fabric, substitutes assist with creating an aesthetic contrast. Additionally, these new or reconstructed assemblies may need to comply with contemporary standards or correct deficiencies that prompted replacement or augmentation in the first place. These upgrades might demand physical and chemical properties that differ from those of the original assembly, such as increased structural capacity, lighter weight, or improved moisture management.

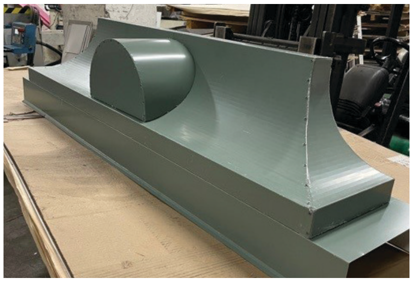
Concerns with Using Substitute Materials

The most common and significant concern with substitutes is *compatibility,* especially when select materials are being replaced in an otherwise existing or original assembly. The new material may have properties that differ from those of adjacent materials, which could make it prone to deterioration or liable to cause damage to surrounding substrates. Differences in coefficients of thermal expansion, for example, can cause adjacent materials to crack or displace as they move differentially over time.

Differences in *vapor permeability, water-tightness,* and *porosity* are also a concern, as they all play a role in moisture mitigation, both from external precipitation and condensation at building interiors. Substitute material insertions should be analyzed to verify they do not introduce excessive moisture into the assembly. They should also allow water to escape, where appropriate. Historic masonry walls can be especially susceptible, as they manage moisture differently than contemporary cavity walls or rainscreens. Condensation can also be a concern in historic roofing assemblies that are replaced with less porous cladding, underlayments, and/or insulation, which can cause moisture to accumulate at the underside of the roof deck, within attic spaces, or within the roof assembly.



Project documents for structural rehabilitation involving substitute materials must be detailed and exacting to yield long-lasting repairs *(left).* At this Juliet balcony, concerns about the aging framing prompted isolated replacement of terra cotta with lightweight substitutes *(right).*



Coated aluminum stands in for copper.

Cast stone replaces limestone at a parapet.

Mitigating moisture infiltration might involve introduction of waterproofing membranes or sheet metal flashings and drip edges where none currently exist or increasing their size or configuration where they do. It could also involve the use of coatings to increase weather durability and waterproofing capacity or to conceal differences between new and old materials.

Other compatibility issues can involve differences in *dimensional stability,* the tendency for a material to maintain its shape and size over time. Clay-based materials like brick and terra cotta gradually expand as they re-absorb moisture, whereas concrete materials tend to shrink as they continually cure. In addition to this elastic deformation, some materials can become plastically deformed when their molecular structure changes due to fluctuations in thermal or structural loading. Over time, these dimensional changes can create microscopic openings that are avenues for moisture infiltration and freeze/thaw damage. On a macroscopic level, they can also cause cracking and displacement.

Substitute materials can also create problems if *strength and weight* are not properly evaluated. Not all masonry is created equal and, depending on type, origin, and applications, can have different degrees of compressive, tensile, and flexural strength, as well as different densities. Similarly, for structural components, stainless steel may be significantly less prone to corrosion than plain carbon steel, but it is also weaker, so dimensions, attachments, and spacing may need to be adjusted to accommodate these differences.

Addressing compatibility concerns is not only a matter of selecting the right materials, but also may require alterations to the unit or assembly. This could involve supplemental reinforcements, anchorage, and support augmentation, or redirecting load paths to address structural concerns.

Substitute joint materials might also need to be used to address concerns with *breathability, adhesive capacity,* or *galvanic action.* For example, cast composite resin does not bond well with mortar unless primed, as it is not porous like masonry or concrete, but does adhere to sealant. However, the less porous cast composite increases the potential for trapping moisture, especially when combined with watertight sealant. When new metal types are introduced, they might require a separation, such as a gasket or coating, to avoid contact with a dissimilar metal. These examples demonstrate the need to consider how substitute materials impact the behavior of the entire enclosure. Moreover, what proportion of the envelope is replaced affects whether substitute materials may present issues or require modifications.

Other concerns include the ability of a substitute to achieve a true *color, texture, or profile match.* Material technology has evolved greatly in recent decades to allow for closer matches, but as many substitutes are machine-fabricated and mass-produced, they do not have the handcrafted or natural character of traditional materials, which often contain more surface variations. Some composite materials with external veneers or coatings have been engineered to create better matches, but they are susceptible to delamination. *Colorfastness* is also an important aesthetic consideration, as traditional materials tend to exhibit better ability to hold color over time. Some substitutes, especially those with coatings or thin veneers, are not dyed throughout their cross-sectional thickness, and can be subject to fading from ultraviolet (UV) degradation and weathering.

Exterior replacements, and associated material selection, can be subject to review and approval by preservation boards or the State Historic Preservation Office (SHPO), depending on landmark status and applicable regulations. In general, replacement elements with higher visibility tend to be subject to greater scrutiny. Substitute materials are more likely to be approved for components on upper floors, parapets, roofs, or non-street-facing facades, or for isolated elements less likely to contrast with adjacent materials. Whether the building is part of a historic district, or a prominent individual landmark, can affect where, how, and which substitutes may be used. The reason for landmark status could also affect the decision to allow a substitute: a building that is landmarked because of a historical event, as opposed to architectural character, might have fewer design limitations.

Sustainability Considerations

Material selection not only influences the performance and longevity of buildings, but also affects health and the environment. At a minimum, the rehabilitation program must consider the impact of *hazardous materials.* If a component to be replaced contains asbestos, polychlorinated biphenyls (PCBs), lead, or other known toxins, it not only requires abatement, but also could be more reason to comprehensively replace the existing material with a substitute. This is especially true if the hazardous compound is friable and will be disturbed by the project, or if it presents ongoing health issues.

Beyond environmental hazards, the project approach should include an analysis of *material lifecycle and disposal.* Many traditional natural materials like stone and clay masonry and old growth wood, if carefully removed, can be repurposed. Stone and clay can be crushed as aggregate in concrete or for roof ballast or landscaping. Wood is inherently biodegradable and can help feed other organisms as it decays.

While some substitute materials contain natural material components, including pre-cast concrete, cement fiber board, and wood byproducts, many contemporary substitutes are synthetic. Some contain plastic, which is not biodegradable but may be recyclable, while others contain bitumen or fiberglass, which can be toxic, cause irritation, and contribute to pollution. Many traditional natural materials also boast a lower *carbon footprint and embodied energy.* Since they are less processed, less energy is consumed in their extraction and fabrication. For synthetics, the energy consumed in material production is often not "green," as it typically pumps carbon into the atmosphere, which contributes to climate change.

Although natural materials can have environmental benefits, using them may not always be the best option for a given project. Technologies are ever-evolving, and production processes continue to be refined as environmental regulations gain further ground. The

^ Substitute materials addressed severe deterioration and weight concerns at this terra cotta cornice.

building enclosure design professional should research products and include sustainability criteria when developing specifications.

Choosing materials that are locally sourced is a good start, as less energy is consumed in delivery. Where possible, re-consideration of material color can affect a building's energy use. Lighter color materials reflect more sunlight and reduce solar heat gain. Increasingly, building codes are stipulating a minimum Solar Reflectance Index (SRI), especially for roofing. Additionally, considering the insulation value of materials, and how their connections impact thermal bridging, is also critical to evaluating energy performance.

It is also important to consider that material selection affects the type and frequency of required *maintenance* for the enclosure. Although the introduction of substitutes may solve some availability, cost, or schedule issues, they may not provide savings in the long term. If materials must be replaced more often or cause adjacent materials to require replacement sooner than anticipated, they are only further contributing to excessive resource consumption.

Substitutes from Antiquity to Today

The use of substitute materials is not a new concept. History shows how their implementation is part and parcel to the evolution of architecture. Although now considered historically valuable, terra cotta was originally employed as a substitute for more expensive stone. For centuries, wood has been painted with sand to mimic stone, as was common practice in American and European manor houses. Romans used concrete in lieu of monolithic stone to achieve efficiency, as poured materials could be installed more quickly.

Buildings are ever-changing, living entities that require regular repair and maintenance, meaning some degree of material replacement is unavoidable. Even routine repairs involve piecemeal replacement of existing elements, such as patching compounds and joint materials. So, the notion of substitutes might be as much a matter of perspective as matching "in-kind" can be.

This discussion may seem relevant only to historic and landmark buildings, but many contemporary structures will one day be considered historically valuable. Modernist structures built in the early 1970s are now eligible for listing on the National Register of Historic

(continued on page 8)

representative projects

Buildings Restored with Substitute Materials

Replacing in-kind is typically the preferred strategy, especially when it comes to historically significant buildings. Still, restoring aging structures while protecting public safety, resolving moisture infiltration, meeting updated building codes, and improving energy performance means that the choice to incorporate substitute materials is far from simple. Add to that the complexities of limited availability, facade ordinance deadlines, and rising costs, and the thoughtfully strategized introduction of substitute materials may be the right choice for some applications.

At Hoffmann, our expertise with building enclosure restoration makes us uniquely positioned to advise clients in meeting preservation challenges. Our project experience includes:

The Taft Apartments
New Haven, Connecticut
Exterior Restoration Incorporating GFRC in Place of Terra Cotta at Cornice

Open Society Foundations Headquarters, New York, NY, *Facade Repairs, Including Replacement of Terra Cotta with Cast Stone.*

Columbia University Medical Center, Mary Woodard Lasker Biomedical Research Building
New York, New York
Facade Repairs and Replacement of Sheet Metal Roof with Aluminum

College of New Rochelle 29 Castle Place
New Rochelle, New York
Parapet Reconstruction Using Cast Stone in Lieu of Limestone

Countee Cullen Library
New York, New York
Exterior Rehabilitation Using Cast Stone Copings in Lieu of Terra Cotta and Aluminum Windows Instead of Steel

Masonic Hall NYC
New York, New York
Facade Rehabilitation Incorporating Cast Composite Polymer Resin to Address Structural Concerns with Terra Cotta

First Presbyterian Church in the City of New York
New York, New York
Facade Restoration and Reroofing, with Asphalt Shingles in Lieu of Slate

Wellesley College, Houghton Chapel, Wellesley, MA, *Roof Coping Replacement Using Cast Composite Resin for Missing Terra Cotta.*

Choate Rosemary Hall, Mellon Library, Wallingford, CT, *Cupola Renovation, with Custom-Milled Cellular PVC in Place of Wood.*

Yale-New Haven Hospital, Tompkins Memorial Pavilion
New Haven, Connecticut
Cupola Restoration with Cellular PVC in Lieu of Wood

Church of the Ascension in the City of New York
New York, New York
Facade Repairs with Galvanized Steel in Place of Cast Iron for Historic Exposed Tension Rods and Plates

Visiting Nurse Association of Northern New Jersey
Morristown, New Jersey
Reroofing and Facade Repairs, with Aluminum Sheet Metal Replacing EIFS

Columbia University, Lerner Hall
New York, New York
Reroofing and Replacement of Glass Block Bullnose with Architectural Precast Concrete Units

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(continued from page 6)

Custom-milled cellular PVC in this restored cupola base resolved persistent wood rot issues.

Places, since they are now 50 years old. The issue of substitute materials has unique challenges for buildings of this era. The industrial products they used, considered revolutionary for their time, might now be obsolete, and they can contain hazardous materials.

Perhaps we should allow buildings to be patchworks which reflect the passing of time and the signature of all those who worked on them. Like cathedrals that took several decades to build and incorporate multiple styles and materials, or historic cities, which took centuries to accumulate, construction is an amalgam of influences. Does an edifice lose its authenticity or cultural value from too much alteration, repair, or restoration? Or might these augmentations enhance, rather than compromise, the original designer's intentions?

On the other hand, design professionals should combat the common misconception that newer is necessarily better. Although substitute materials are subject to regulated engineering and testing, in the greater history of material use, many of them are still relatively new. It is not entirely known how some of them will perform in the long term, either independently or as part of an existing assembly. The answer to which material to use is not necessarily straightforward and should be evaluated on a case-by-case basis. ■

JOURNAL is a publication of Hoffmann Architects + Engineers, specialists in the rehabilitation of building exteriors. The firm's work focuses on existing structures, diagnosing and resolving problems within roofs, facades, windows, waterproofing materials, structural systems, plazas/terraces, parking garages, and historic and landmark structures. We also provide consulting services for new building construction, as well as litigation and claim support.

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265 Church Street, 16th Floor
New Haven, CT 06510
203-239-6660

462 Seventh Avenue, 20th Floor
New York, NY 10018
212-789-9915

277 S Washington Street, Suite 210
Alexandria, VA 22314
703-253-9800

www.hoffarch.com

Editor/Production: Alison Hoffmann