# DETAILING DISSIMILAR MATERIALS

COURTESY HOFFMANN ARCHITECTS + ENGINEERS

Transitions between different materials and assemblies require thoughtful detailing to avoid premature failure.

## LEARNING OBJECTIVES

After reading this article, you should be able to:

- **IDENTIFY the key principles and challenges associated with detailing and joining dissimilar materials in building enclosure design.**
- **UNDERSTAND the importance of material compatibility, sacrificial components, and prevention of galvanic action in ensuring the longevity and performance of building elements.**
- **LEARN strategies for addressing differential movement between materials, including the selection and implementation of appropriate joint designs and connections.**
- **GAIN knowledge of effective techniques for surface preparation, system terminations, moisture and air infiltration mitigation, and the use of isolation joints and membranes in building enclosure design.**

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**Detailing and joining individual material components into a unified whole** is essential to the technical art of building enclosure design. Even basic enclosure details consist of multiple components, each with distinct material properties and performance characteristics that demand thoughtful consideration. To construct a long-lasting assembly, the designer must consider each of the parts, their connections to one another, and how they behave as a unified whole.

Within building assemblies, connections and transitions between dissimilar materials may be concealed, but their impact on the longevity of the enclosure is significant. When those elements join, it is often the connection of these disparate components that determines whether an enclosure performs as

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**Pictured: window flashing tie-in to adjacent air barrier prior to application of spray foam insulation**

expected or succumbs to premature failure.

The fundamental factor critical to a durable and lasting connection between dissimilar components is material compatibility. Materials that behave similarly are naturally most compatible, which reduces the need for specialized or complex details. To join various materials in an enclosure assembly, design professionals must account for the complex ways these different elements interact.

Using detail drawings, knowledge of material properties, and experience with known material interactions, enclosure specialists anticipate and design for the three-dimensional changes and chemical reactivity at each detail or system transition. The building exterior specialist's job is to streamline these transitions, accounting for material properties and limitations, manufacturer warranty requirements, construction feasibility, and other key considerations. In short, it is the enclosure consultant's job to see that no detail is overlooked.

**Material Compatibility**

When designers refer to "material compatibility," they are looking to see if distinguishing qualities harmonize well together or antagonize one another, similar to how people build relationships. While for interpersonal compatibility we might look at gregariousness, fastidiousness, or ambition, architects and engineers consider measurable properties for building materials, including hardness, compression strength, elasticity, tensile strength, coefficient of expansion, and plasticity. For contiguous elements, detailing dissimilar materials requires accounting for differences in properties and accommodating those differences in the development of the detail.

Compatibility begins with choosing appropriate materials, with awareness not only of the function of the building element, but also how it interacts with adjacent components. Aesthetics is always a consideration, but specifying suitable materials also requires evaluating how each material responds to different climactic factors for a given project site, including annual temperature range, precipitation, wind, humidity and the consequent tendencies of each material to expand or contract.

There are instances where some materials may be better suited to a given purpose than others. For example, while both silicone and polyurethane sealants are common, knowing which type to use where will determine life expectancy of the joint. A horizontal surface prone to standing water, such as a rain gutter, could use sealant composed of durable and weather-resistant polyurethane, an organic polymer, which offers the advantage of excellent abrasion resistance and the properties to withstand prolonged exposure to standing water. In contrast, a vertical joint, like that between glass and frame, typically uses the more flexible, UV-resistant silicone. If the surface is to be painted after application, however, silicone is best avoided, since its inorganic chemical structure is incompatible with most coatings.

It is important that sealant be compatible with all materials being joined in any given detail. Most sealants have multiple suitable substrates, so a masonry-to-metal joint, for instance, can be addressed with a single sealant. However, surface preparation and requisite primer, if any, for the masonry will likely differ from those for metal.

Such nuances in suitability are common to nearly all building materials, from factory-made synthetics to naturally extracted elements. Historically, builders understood that soft stones like limestone and marble were not appropriate for construction of the façade below the water table, which was usually finished with more durable brick or granite. Where one material transitions to the next, however, has always demanded extra attention, as the ideal pointing mortar for limestone and that for granite are not equivalent.

In addition to performance, choosing appropriate materials for specific details requires close examination of performance limitations. Materials such as select fluid-applied waterproofing systems, self-adhered flashing membranes, or air barriers can withstand only limited exposure to ultraviolet light before becoming damaged. Other materials, especially coatings, must be applied to dry surfaces and, following application, must be protected from moisture until cured or covered with other enclosure components. Underfired brick, or salmon brick, which is typically used for the inner wythes of a load-bearing masonry wall, will deteriorate rapidly if laid as part of the outer cladding. Even when fastened appropriately, polymer-based façade trim will warp and detach when coated with a dark color. The enclosure specialist specifies job conditions, construction sequencing, and finish treatments to design strong details that perform and endure.

**Sacrificial Components**

Where dissimilar materials join, one element is typically sacrificial, that is, designed to succumb to the forces of pressure, corrosion, time, and weather. It is easier, less costly, and less intrusive to the building assembly to repair a failed sealant or mortar joint than it is to restore the adjacent masonry or façade element.

Mortar joints are intended to be sacrificial, weaker than the surrounding brick or stone. Softer lime-rich mortars can self-heal as a structure settles. In a misguided repair effort to strengthen wall systems, maintenance teams sometimes repoint with mortar that is stronger than the surrounding masonry, resulting in a lacework of intact mortar surrounding crumbling stone units.

Like mortar, sealant is intended to be more flexible than the components it joins. Often the first point of failure in an assembly, sealants are designed to be sacrificial and require maintenance. These joints take the brunt of expansive and contractive forces and, like all materials, fatigue over time. Still, better to account for the known expense of periodic sealant replacement than to bear the cost and disruption of a sudden failure at a fractured beam, column, or wall.

**Galvanic Action**

For metals, the sacrificial component phenomenon is illustrated through the process of galvanic action, whereby one metal corrodes when in contact with another that is higher on the galvanic series. Noble metals, least prone to corrosion, are at the top of the series, with more susceptible metals at the bottom. Copper, for instance, is higher on the galvanic series than steel; when the two are in contact, the steel will corrode.

Galvanic action occurs when a conductive pathway is present to allow ions from one metal to migrate to another. Such a conduit is readily available in the form of dissolved salts in water. Minerals in brick masonry, deicing salts on walking

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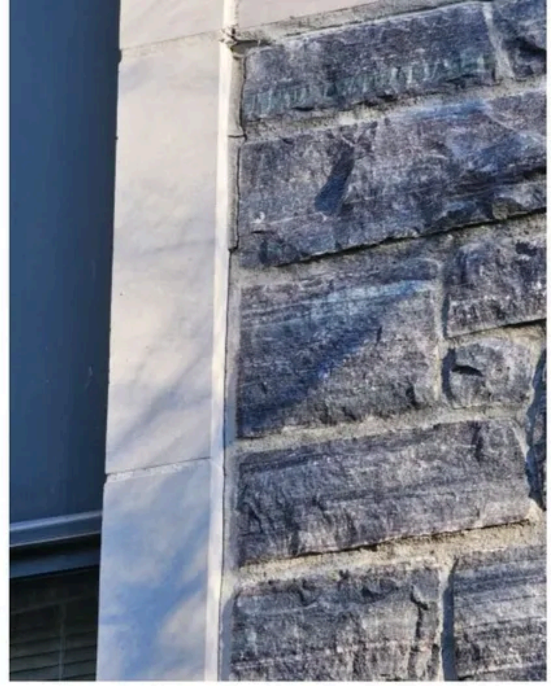
**Adhered waterproofing installed into the base of a masonry cavity wall creates an integral wall flashing.**

surfaces, saline elements in stone, and a host of other building materials are all excellent sources of these corrosion-accelerating electrolytes, so attention to isolating dissimilar metals is critical to preventing accelerated deterioration.

Metals need not be in constant, direct physical contact for galvanic action to take place. Intermittent friction-based connection is often sufficient, and even materials that aren't directly adjacent can succumb to galvanic action through water migration. The interaction of dissimilar metals in historic window hardware, such as a brass pulley with a steel chain, can result in a broken sash chain, simply from the combination of air vapor and surface friction. The chemicals naturally present in cedar and other wood or chemicals used to create pressure-treated wood will corrode some metals, so fasteners must be corrosion-resistant, such as hot-galvanized or stainless steel, to provide a durable connection. Rainwater runoff from a copper scupper will corrode a zinc alloy-coated steel downspout. For metal roofs, fasteners and accessories should use the same metal as that of the roofing.

In addition to choosing similar metals, other methods for preventing galvanic corrosion include applying neutral materials to separate metals and plating or coating to create a sacrificial layer without compromising the underlying material. Passivation uses a chemical reaction to create a micro-coating of protective material that is less reactive to corrosion.

For concrete construction, cathodic protection can be used to prevent corrosion of embedded reinforcing steel. By incorporating another metal, such as magnesium, aluminum, or zinc, that is lower on the galvanic series, passive cathodic protection offers up the secondary metal as a sacrificial anode. The more reactive metal undergoes the corrosion reaction instead, sparing the steel rebar. Cathodic protection can also be achieved through an impressed current, which drives a protective electrochemical reaction. By creating an electrical potential difference between the steel and an inert anode connected to a power source, an applied current causes the steel to become the cathode of an electrochemical cell, which stops the corrosion reaction.



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**Deterioration at a limestone-to-granite mortar joint**

### Differential Movement

Differing rates of expansion, contraction, and deformation need to be considered when joining materials with different properties within an as-


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**Pictured: waterproofing at masonry cavity wall relieving angle**

sembly. When heated, different materials expand at different rates, expressed as the coefficient of thermal expansion. For adjacent materials in an enclosure system, details must account for differing rates of expansion, not only for the two materials being joined, but also for the joining material.

Where two connected wall components have dramatically differing coefficients of thermal expansion, strategies for addressing continuity within a wall system must allow for these varied rates of movement. For example, brick is known to absorb moisture from the environment and expand over time, whereas concrete shrinks as it cures. When the two are tied together as part of the same assembly, as in a masonry cavity wall, the design must accommodate this behavior. Slotted angles at anchorage points are one solution to allow for differential movement between brick veneer and a concrete backup.

**Joints and Connections**

Where two or more dissimilar building materials meet, forming a joint, or connection plane, the size of the joint is based on the anticipated movement between the two materials. Different types of joint designs serve different functions in the building enclosure, with some designed to allow for high degrees of movement from compression and expansion, and others functioning as material separators.

The massing of a building system determines the expected degree of expansion and contraction at each joint or transition. Building enclosure specialists anticipate cumulative dimensional changes by incorporating larger joints at intersections between larger spans of material, or by dividing larger expanses with smaller joints more frequently throughout the material plane.

*Expansion Joints*

Designed to accommodate the impacts of dimensional changes, expansion joints are installed between materials in the same plane. They are typically located at or near building corners, offsets, setbacks, wall intersections, and changes in wall height, as well as where the wall assemblies change. They may also be used at masonry veneer supports or where the wall function or climatic exposure changes. Expansion joints are important for exterior concrete and masonry applications, to account for expansion during heat exposure. Maintenance of the expansion joint is crucial to its performance, and replacing a damaged expansion joint should not be deferred.

## Detailing Penetrations

***As one of the most common sites of leaks, penetrations are worth the extra attention to detail.***

The principles of anticipating differential movement, preventing galvanic corrosion, and specifying appropriate joint compounds apply equally to penetrations as they do to any other transition between building elements. Penetrations, however, also create a void in an otherwise intact assembly, passing a foreign material through a uniform surface. Adequately protecting this breach from leaks, corrosion, wear, and degradation requires skilled planning and execution.

Penetration materials differ from those of the surrounding wall or roof, as well as from the material used to seal the opening. Often, there is a third material, such as waterproofing or roof flashing membrane, that requires adhesion to both the substrate and the penetrating material. Surface preparation is critical. Metal pipes require preparation to white or bright metal prior to primer application, while PVC demands cleaning and use of compatible sealants and adhesives. Penetrating fasteners must undergo waterstopping treatment, such as butyl tape or mastic for a fastened roof drain, prior to installation.

Varied coefficients of thermal expansion challenge efforts to create a watertight moisture barrier, as the design must also allow for differential movement. Joint widths should be sized appropriately to permit dimensional changes while maintaining a durable seal.

Designing to accommodate the distinctive properties of each material, while anticipating their behavior in relation to one another, will improve performance and longevity at these complex intersections.

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**Anything that passes through the roof or wall assembly must be meticulously detailed to prevent water infiltration.**

*Sealant Joints*

On average, sealant is designed to perform for five to seven years. Life expectancy is dependent on many factors, including adequate material storage conditions, joint surface preparation, tested adhesion to substrates, and tooled joint profile. Installed and finished in the field, sealant ideally has an hourglass-shaped section, with the depth of the joint at the center being half of the joint width.

This profile relies on installation of a backer rod to give the joint its shape as it cures, as well as serve as a bond breaker that allows the joint to expand and contract freely. Backer rods are usually round, flexible lengths of foam sized to twice the diameter of the joint width. The backer rod is squeezed into place using tools that prevent twisting, tearing, puncture, or other damage to the material. Placement within the joint to achieve the correct profile is critical. Backer rods placed too deep or too shallow, or those that are deformed or damaged, will adversely affect the joint profile and, consequently, joint performance and lifespan.

When a joint is too narrow or shallow for a backer rod detail, a bond breaker is used. Bond breaker tape is a polyethylene film coated with adhesive backing used to prevent three-point adhesion that would restrain joint movement. Another option is pre-formed sealant joints, which are secured with adhesive. Additionally, expansive sealants can conform to joint irregularities and may be considered where conventional sealant is inadequate.

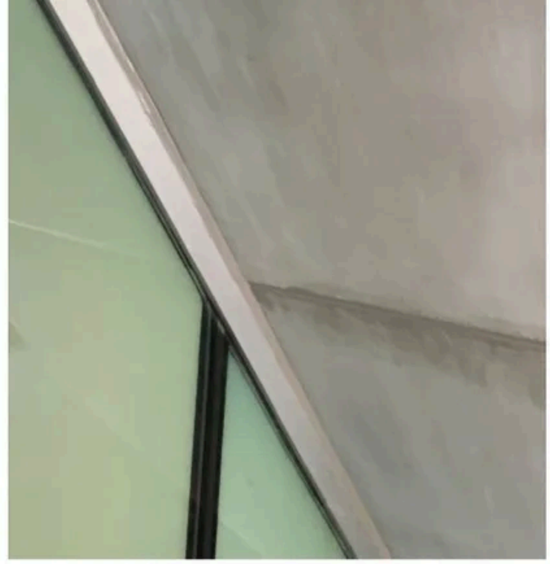
*Mortar Joints*

In masonry construction, mortar joints not only play a key aesthetic role, but also secure the assembly without undue rigidity. High strength mortar leads to cracked and spalled masonry units, which expand and contract with fluctuations in temperature and moisture; mortar that has deteriorated and lost its binder can lead to wall displacement and deformation, such as bulging.

Mortar selection is based on type of construction, masonry material, and location of application (interior versus exterior), as well as the era and style of the building. For historic restoration, using repointing mortar that is softer than the masonry is critical to preserve its role as the sacrificial component and protect aging brick or stone.

*Bond Breaks*

A potential joint component, a bond break is another way to separate dissimilar materials and allow independent movement. Where it is not feasible to align expansion joints in one material with another, for instance those in brick paving and the concrete slab below, a bond break allows for and corrects the discontinuity. A bond break is typically formed by a thin material, such as a polyethylene sheet.



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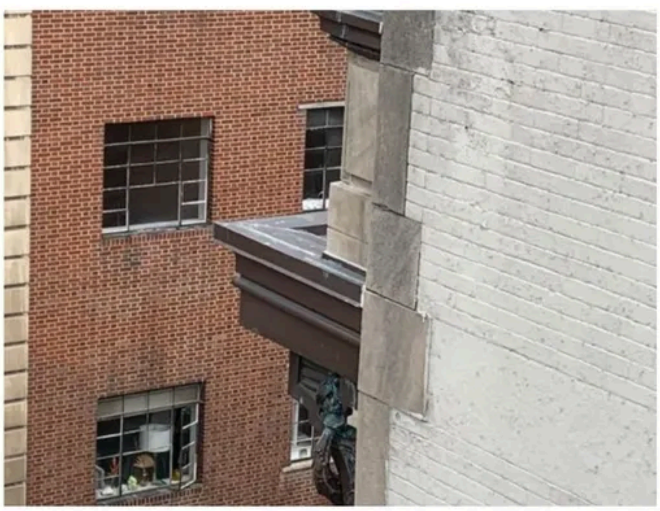
**A complex connection: stucco expansion joint, metal termination cap, and glazing joint.**

**Pictured: a primary limestone facade transitions to brick masonry on the non-street-facing walls.**



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## Isolation Joints and Isolation Membranes

***Where building materials need to move relative to each other with complete discontinuity, isolation joints and isolation membranes are the solution.***

**By allowing elements to move independently, isolation materials enable proximal components to form a unified assembly while responding to different forces. For instance, two differently supported building components, such as a column and slab, would succumb to restraint cracking during differential settlement and contraction if joined rigidly. Instead, an isolation joint offers each the ability to move according to its tendencies without straining the other.**

**Selection of isolation joint materials, which include asphalt-impregnated fiberboard, cork, rubber, and neoprene, is determined by performance requirements and calculated degrees of movement, as well as environmental factors such as chemical exposure and moisture levels. Value of the structure and material costs are also considerations.**

**Similarly, isolation membranes can help prevent cracks and fractures in a horizontal surface where differential movement is anticipated. They are often specified for flooring systems where the subfloor or concrete slab will be subjected to significant structural shifts, such as from building settlement or temperature-driven expansion and contraction. Materials with different coefficients of expansion can lead to cracking unless they are isolated from one another. The flexible material of an isolation membrane, also called an anti-fracture membrane or crack isolation coating, acts as a buffer between these disparate elements, absorbing stress and allowing the materials to move freely.**

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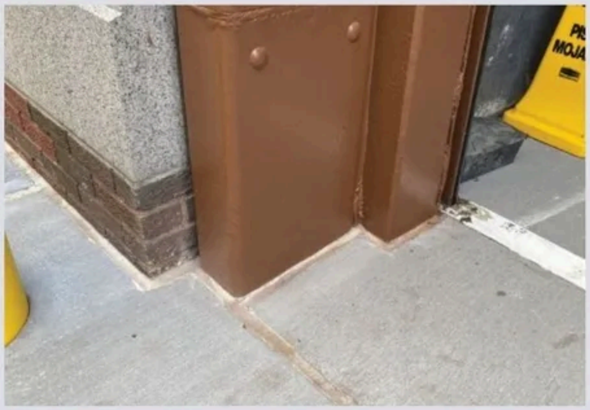

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**Isolation joints allow adjacent materials to move independently.**

### Surface Preparation for Joints

Even when the correct mortar or sealant is selected, installation can fail if the surfaces receiving the joint material are not properly prepared. Surface preparation includes removal of residue, debris, and dirt to yield a sound substrate. If a substrate is failing or deteriorated, repair or replacement may be required prior to installing a new sealant or mortar joint.

Some substrates, such as brick, might require application of a primer prior to sealant installation, while others, typically concrete, do not. The manufacturer's installation instructions typically provide guidelines for surface preparation.

### System Terminations

System terminations involve roof and façade edges, as well as changes in materials, such as a brick wall system meeting a stone sill, or metal cladding transitioning to glazed curtain wall. Where more intricate, eye-catching cladding at the primary street-facing façade transitions to less expensive materials at the side (secondary) and rear (tertiary) building façades, attention to detailing is necessary to prevent problems with differential movement, galvanic action, water infiltration, and resultant façade displacement. Material changes in other areas, such as watercourses and belt courses, impact the design of the underlying flashing and relative position of floor lines, and require careful detailing as part of the design process.

Waterproofing terminations, another common source of problems, are often overlooked. Without specific design guidance from the architect or engineer, the construction team may inadvertently compromise the entire waterproofing assembly through faulty termination of the system at parapets, foundations, roof edges, penetrations, and other vulnerable locations.

Where one assembly meets another, the transition should consider both performance and aesthetics. For instance, a huge sealant joint not only is unsightly, but also is more likely to fail than an appropriately designed, sized, and correctly installed joint.

### Moisture and Air Infiltration Mitigation

Preventing unwanted air and moisture migration protects the building enclosure from premature deterioration, mold and vegetative growth, and poor thermal performance. Continuity is critical, whether the barrier is one material or multiple connecting materials. Detailing transitions between disparate components of the air/vapor barrier assembly is essential to the successful functioning of the system.

Beyond air and vapor barriers, flashings provide a critical moisture management function in the building enclosure where one material or system transitions to another. Flashings direct water out and away from the enclosure, so moisture does not collect and remain trapped within foundation, wall, and roof assemblies. Fluid-applied flashings are intended to tie in to roof and waterproofing systems, with a positive lap to shed and drain water. Through-wall flashing assemblies can be metal, or other materials that differ from the façade and structural materials in the surrounding assembly, so the movement and anchorage of these differing materials must be considered. When designing the tie-in of the flashing material to an air barrier, the enclosure consultant also needs to account for the properties and compatibility of the flashing and air barrier materials relative to those of the façade enclosure and supporting structure.

Achieving a high-performance building enclosure depends on precisely detailed material connections. Without an appropriate seal around windows, doors, and other penetrations, moisture-laden air can infiltrate the controlled space of the building interior, leading to occupant discomfort and compensatory overuse of the building's heating and cooling systems. Balancing smooth operability of windows and doors with a tight-fitting seal relies on well-designed weatherstripping, expansion foams to seal the perimeter, rubber, or metal and plastic tension seals. Understanding which approach is best for a given application is the role of the building enclosure consultant, who can also oversee blower door testing and other functional performance analyses to quantify and fine-tune performance at façade penetrations.

**The Devil Is in the Details**

Considering the junctions between materials and anticipating how adjacent systems will interact can make the difference between a building that looks great for 50 days or 50 years. Without attention to the sometimes widely varying properties of different enclosure elements, a building will quickly succumb to the destructive forces of nature. Metals will corrode, concrete will fracture, brick will dislodge, water will infiltrate, and, eventually, the cost of repairs will far exceed any initial expense incurred by attending to these details from the outset.

Meticulous roof, façade, and fenestration details anticipate the behaviors of the various building materials that make up a given assembly. Designing to accommodate the tendencies of materials to shrink, expand, shift, slide, oxidize, or corrode increases the lifespan of building elements and reduces maintenance demands. Thoughtful transitions at air, vapor, and thermal barriers also contribute to building energy efficiency and can reduce long-term operational costs by optimizing envelope performance. While it may seem superfluous to expend so much attention on such small details, it is precisely these minute interstices that really can make or break a building.+

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**Transition details, such as drip edges and weep holes, are essential to moisture management.**

**EDITOR'S NOTE**

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