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Journal

Sealant Joint Solutions

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In new construction and rehabilitation projects, sealant joints are often given short shrift when it comes to time and attention. And when it comes to budget, too: sealants generally comprise the lowest percentage of a project's overall cost. That's surprising when you consider all that sealants are asked to do.

Facade sealant replacement begins with complete removal of existing sealant and backer rod.

As modern buildings have moved away from mass walls toward lighter, more pliant construction, designers rely on sealants to buffer those moving parts. With their multiple wythes and drainage channels, mass walls were designed to absorb and shed water before it reached the inner surface of the wall. Curtain walls and lightweight cavity walls depend on sealant joints not only to accommodate movement, but to keep the building interior dry. That's a lot to ask of a building element, especially one usually afforded only passing consideration.

Precast concrete construction relies on sealant more than any other building type. Parking structures, in particular, have miles of sealant joints that must be maintained and, periodically, replaced. These joints frequently suffer from poor design and/or installation, as well as damage from high-heeled shoes and snow plow blades.

When sealant joint failure occurs, it can wreak havoc on the building envelope. Many joints are difficult to repair, and some concealed joints may be impossible to fix without demolition and reconstruction. That's why it's so critical to design joints correctly, and to specify and properly apply an appropriate sealant. Before having a handyman attack cracked or missing sealant with a caulk gun, consider the substantial costs of rehabilitating water damage should that caulk fail. In the bigger picture, it's worth spending the time and energy on well-designed sealant joints to prevent premature degradation of building materials.

Sealant Joints: An Age-Old Problem

Although naturally-occurring bitumen- and asphalt-based materials have been used as building sealers for centuries, modern polymeric sealants were developed relatively recently. Acrylics and polyurethanes emerged in the 1930s, while water-based epoxies and silyl-terminated polyethers weren't developed until the 1980s and '90s, respectively. New sealant types, including

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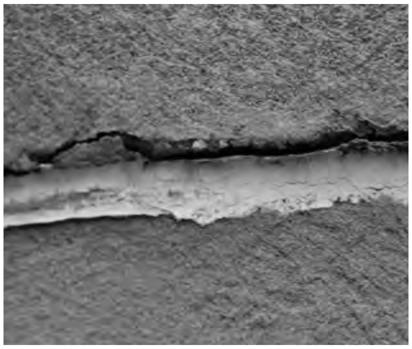
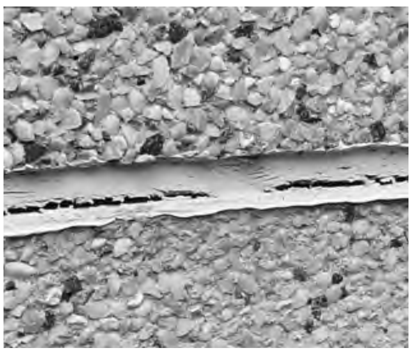


Adhesive failure: Sealant pulls away from the substrate.



Cohesive failure: Sealant tears within itself.

proprietary mixtures, regularly appear on the market, each claiming to surpass the performance of previous generations of sealant products.

Modern sealants are composed of two basic elements: an elastomeric compound for flexibility, and some type of filler. During the mid-twentieth century, asbestos was a common sealant component, and poly-chlorinated biphenyl, or PCB, was often added to impart desirable properties to the sealant. Unfortunately, subsequent research has linked both compounds with cancer, and the resultant clean-up process has led to no end of trouble for building owners and rehabilitation teams alike (see sidebar on page 5).

Elastomers do just what their name says: they stretch. Sealants are usually polymers, composed of more than one type of elastic material. These pliable compounds are used to bridge gaps at moving joints, where two building elements that move differentially intersect, as well as at static joints, which are relatively stable. Today's sealants vary in composition to accommodate different applications, whether a high-movement expansion joint, a structural glazing seal, or a concrete control joint.

Sealant Types and Properties

For residential and commercial applications, the six most common types of sealants are water-based latex, solvent-based acrylic latex (acrylics), butyl, polysulfide, silicone, and polyurethane. No one sealant type is universally better or worse than another; some are better suited to a given application than others due to their physical and chemical properties.

Latex sealants are popular for residential use because they are easy to apply, adhere well to most substrates, and are generally paintable. For low-movement applications, they are an economical option that gets the job done. Where they fall short is in situations where a high movement capability is necessary, such as for high-rise buildings and moving joints. Latex is also prone to shrink, pulling away from the substrate and leaving open gaps where water can penetrate.

Acrylics are mainly used in exterior applications, where their ultraviolet stability puts them at an advantage over water-based latex. Acrylics are also less likely to shrink over time. On the downside, acrylics can be difficult to tool, and they don't perform well in high-movement areas.

Butyls adhere well to a wide variety of substrates, but they can be difficult to apply due to their stringy consistency. Butyls also have poor resistance to abrasion and shear forces, which limits their performance in demanding applications.

Polysulfides can accommodate submerged applications, such as in a fountain or pool. They have excellent flexibility, even at low temperatures, and they exhibit little shrinkage or UV degradation. However, they are expensive, and they tend to have high levels of volatile organic compounds (VOCs). At ten to twenty years, the long life expectancy for polysulfides may help compensate for the up-front costs, particularly considering the difficulty of re-sealing an underwater surface.

Silicones have excellent thermal resistance, dynamic movement capability, and good adhesion, but they are easily vandalized and tend to collect dirt. For some substrates, staining may be an issue. In addition to general sealant applications, silicones are also commonly used as structural glazing sealants, securing sheets of glass to framing elements. Of all the common sealant types, silicones tend to be the most expensive—but they also have the longest service life.

Polyurethanes adhere well to most surfaces with little substrate preparation, making them the go-to sealant of many contractors. Their excellent resistance to abrasion and shear forces, along with strong adhesion and movement capability make them a good choice for applications, such as plazas, which demand durability and resilience.

When selecting a sealant, consider the properties that most impact the specific application at hand. Key sealant properties to evaluate include:

Consistency. Sealants are available in *pourable* or *non-sag* formulations. Pourable sealants have a fluid consistency for use in horizontal joints, where they are self-leveling. Non-sag sealants are thicker and won't run down sloped or vertical joints.

Durability. The expected service life of a sealant under ideal conditions may not be the same as the actual field lifespan, especially if the sealant was misapplied or incompatible with the substrate. Generally speaking, silicones have the longest service life, estimated at 20 years or more, while some acrylics and butyls last little more than five.

Hardness. The harder a sealant is, the greater its resistance to traffic and vandalism. However, as hardness increases, flexibility decreases, so the trick is to find the right balance of damage resistance and movement capability for a given situation.

Exposure resistance. The best exterior-grade sealants perform well in response to sun, temperature extremes, and moisture. Measures of exposure resistance include flexibility at low temperatures, freeze-thaw resistance, UV stability, and susceptibility to heat aging.

Movement capability. The higher a sealant's movement capability, the more elongation or compression it can withstand without failure. Movement capability is expressed as a percentage of the joint width: e.g. a sealant with ±10% movement capability in a one-inch joint can stretch to 1.10 inches—or contract to 0.90 inches—and recover.

Modulus. Short for "modulus of elasticity," modulus refers to sealant stress at a given elongation. Low-modulus sealants usually have high movement capability, and vice versa, although this is not always the case. Low-modulus sealants are generally used for delicate substrates, for which it is desirable to have low stress at the joint edge. High-modulus sealants are best used for static, non-moving joints, because they exert a very high force on the substrate when stretched. Medium-modulus sealants are general-purpose products that balance stress at the adhesion surface with stiffness of the sealant.

Adhesion. The ability of a sealant to adhere to construction materials is an essential property to consider. ASTM International offers test methods, such as ASTM C794, to evaluate the adhesion of elastomeric sealants, and manufacturers also provide data on sealant adhesion for various substrates.

Staining. The components of some sealants may leach into porous substrates, particularly natural stone, leaving a visible stain. To evaluate compatibility with the substrate, even sealant rated as non-staining should be tested in an unobtrusive area before use.

VOC content. Emission of Volatile Organic Compounds from building products is regulated at the state and regional level. For occupied buildings, VOCs are a particularly important consideration. While most manufacturers have developed low-VOC sealants, some types of sealant have lower levels than others. Solvent-based sealants tend to have higher levels of respiratory irritants and environmental toxins, but VOC content varies widely by product.

Ease of application. Curing characteristics and *toolability* are the two major factors affecting a sealant's ease of application. Toolability refers to the ease of achieving a smooth surface of correct geometry. Curing properties vary widely, from fast-curing sealants to those, such as polyisobutylene, that are designed to remain uncured.

Cost. As is the case with most building products, cheapest is not usually best. In general, higher cost means higher performance. That not withstanding, opting for a high-performance sealant when a less expensive alternative would do the job may mean you're overspending. Scrimping on sealants is not likely to do the prudent building owner any favors, though, as replacing

Sealant misused to repair mortar joints.

Damage to plaza sealant caused by high heels.

Failure to maintain sealant joints can lead to severe deterioration and water entry.

Peel tests are used to evaluate sealant elongation and adhesion.

failed sealants is nearly always more expensive than is selecting the right sealant in the first place.

Causes of Sealant Failure

Incorrect Joint Design

One of the most common causes of sealant failure stems not from the sealant itself, but from the size and spacing of the joints. Joints must be sufficient in number and in spacing to allow for seismic forces, thermal cycling, and differential movement of substrate materials. Different sealants have differing abilities to accommodate *shear stress*, caused by the faces of the joint sliding past one another, along with *expansion* and *contraction* as fluctuating temperatures cause the joint to widen or narrow.

Joints that are too narrow or too widely spaced may force sealant to stretch beyond its capacity, which can cause the sealant to pull away from the substrate (*adhesive failure*) or to tear within itself (*cohesive failure*). Expansion of the substrate may compress the sealant beyond its tolerance, causing it to extrude out of the joint. A joint that is excessively wide may not be able to accept sealant at all, as the sealant is likely to slough out of the large gap.

Properly designed sealant joints generally have a 2:1 width-to-depth ratio, a configuration that allows the joint to accommodate movement most effectively. In addition, many manufacturers stipulate maximum and minimum dimensions for the sealant bead to perform within its movement capability.

Inappropriate Sealant Selection

In addition to correct joint design, selection of a sealant product that can withstand anticipated building movement is critical to avoiding premature failure. Inadequate provision for movement, either by underestimating the amount of movement or by using a sealant with insufficient movement capability, can cause even correctly proportioned joints to fail.

Fountains, parking garages, plazas, schools, and other sites subject to vandalism, water, and weather conditions demand sealant with superior abrasion resistance. High-heeled shoes, the bane of the precast concrete parking garage owner, are notorious for puncturing sealant at joints. Special additives and hardeners are manufactured specifically to resist damage from high heels. Pick-proof sealants can withstand vandalism, but these harder sealants tend not to accommodate much movement.

Substrate compatibility is another major consideration when selecting a sealant. Some sealants can leach chemicals that may discolor or degrade porous substrates, such as brick masonry and stone. Under stress, a sealant that is stronger than its substrate can cause cracks and spalls, as force is dissipated within the weaker material. This phenomenon is common with Exterior Insulation and Finish Systems (EIFS).

Existing coatings can also prove problematic for sealant performance. Fully removing such coatings—or selecting a sealant compatible with the existing product—is necessary to achieve adequate adhesion. Because many surface sealers are clear and, therefore, difficult to detect, it is important to conduct a field adhesion test before full-scale sealant replacement.

Improper Application

The number-one concern in the sealant application process is surface preparation. Given how often sealant failures related to poor surface preparation occur, and how costly such failures can be to rehabilitate, it would be reasonable to assume that a top consideration for sealant installers would be the diligent and thorough cleaning and, if required, priming of joint surfaces. Not necessarily so. Especially for workers who have "always done it this way," manufacturers' recommendations for preparing the substrate may have little bearing on what is actually done in the field. At a minimum, surfaces must be clean and dry. Too often, though, even this simple stipulation is ignored. Dirty rags, incorrect or contaminated solvent, lint, and residue from existing sealant are

Compare the non-staining sealant at the top of this image with the sealant at the bottom, which has discolored the substrate.

just some of the many ways in which a sealant joint can be compromised.

A number of sealant types require surface primers prior to application, depending upon the substrate. Primers can enhance adhesion, prevent the sealant from diffusing into the substrate, and emulsify dirt particles remaining on the surface. The advantage to using a sealant that does not require a primer is that there is less room for error on the part of the installer, and skipping the priming step cuts down on application time and cost. However, some sealants that do require a primer perform better overall than do their direct-application counterparts, so the additional time and oversight required for primer use may be worthwhile in the long run.

Weather conditions on the day of application can affect sealant performance. Ideally, sealant should be installed at the median of the design range. That means that the sealant has room to elongate or compress to accommodate fluctuations in temperature. If the sealant is installed in very cold weather, for instance, the substrate has shrunk and the joint is at its widest. As the weather warms and the substrate expands, compressive forces may exceed the sealant's tolerance, leading to failure. The converse is also true; sealant installed in hot weather may stretch beyond capacity as the weather cools and the substrate contracts. Sealant installed at moderate temperatures retains the flexibility to accommodate the upper and lower ends of the design range.

Sealant viscosity also varies with temperature. If the temperature is very hot, sealant may sag; whereas, cold sealant may be thick and difficult to tool. High humidity, frost, dew, or dampness can also lead to failure, as sealant will not adhere properly to a surface that isn't dry.

PCBs in Sealant

Polychlorinated biphenyls, or PCBs, were a common additive to sealants from the 1950s until they were banned in the United States in 1979. Because of their elasticity and chemical stability, they were added as plasticizers to building sealant used for windows and masonry. Exposure to PCBs can cause cancer, as well as endocrine disruption, immune suppression, liver damage, reproductive system failure, and neurotoxicity.

PCBs are regulated under the Toxic Substances Control Act, but state and regional regulations vary as to their safe disposal. Because PCBs can leach into the surrounding substrate or soil, abatement may involve demolition and/or excavation, adding substantial time and expense to a sealant replacement project. At a minimum, containment measures must be put in place during rehabilitation to prevent PCB-containing dust from becoming airborne. Site access should be limited, and workers must wear appropriate protective clothing and respiratory equipment. Removal methods should minimize heat generation, as PCB gases may be released into the air in response to high temperature. Also avoid grinding, which produces dust and may lead to aspiration of PCBs.

PCBs can be a formidable obstacle to sealant joint rehabilitation. However, the potential health consequences of negligence outweigh the inconvenience and expense of proper abatement. ■

Correct joint preparation and tooling are essential. Using a *backer rod* prevents three-sided adhesion for moving joints, and it helps to achieve correct sealant depth and profile. Without a bond-breaker at the back of the joint, sealant adheres to all three sides, leading to adhesive or cohesive failure—or both. To understand how this works, picture stretching a rubber band. This is how a sealant joint is meant to operate: your hands are the substrate, stretching and relaxing the rubber band, which represents the sealant. Now imagine grasping the rubber band with your hands very close together, leaving only a tiny bit of the band to stretch and contract. So too does three-sided adhesion restrict elongation, as the bond area imposes additional stress on the sealant.

Sloppy tooling may result in voids, gaps, and irregular sealant thickness, causing stresses to act unevenly along the joint. Ideally, sealant should follow the curve of the cylindrical backer rod, with a concave tooled surface, such that it resembles an hourglass in cross-section.

Reversion

Some organic sealants, especially polyurethanes, have the potential for reversion failure, in which they return to an uncured or gummy state in response to ultraviolet light exposure and moisture. Although manufacturers became aware of this problem more than a decade ago and have modified their products accordingly, owners and managers of buildings with older sealants should be on the lookout for signs of reversion. Keeping tabs on the consistency and performance of sealants should be part of a routine maintenance program.

Imprecise Specification

Sometimes, incorrect sealant use is not entirely the fault of the installer. For instance, contradictions between drawings and specifications, or instructions that go against relevant design standards or manufacturers' guidelines, may cause unnecessary confusion. Careless material specification may stipulate particular sealant properties, while specifying sealant products that do not have those properties. Drawings and documents may be unclear as to which sealant types are to be used in which locations. Any number of other errors and inconsistencies in the contract documents can leave the installation open to guesswork—with a high potential for failure.

Performance Testing

Before embarking on a sealant replacement project, it's prudent to assess the suitability of the sealant product for the given application. A good place to start is manufacturer verification. Is the sealant compatible with the substrate? Will the product meet adhesion and elasticity requirements for the estimated joint movement? Is the sealant prone to discoloration or staining? Manufacturers can answer these and other general questions to verify the properties of a sealant under consideration. However, field conditions vary, and it's a good idea to test products on site whenever feasible.

Peel tests for adhesion involve applying sealant to a test area, allowing it to cure, and evaluating the elongation prior to fracture or loss of adhesion.

> "The number-one concern in the sealant application process is surface preparation."

Especially for older buildings, it is important to assess multiple substrates and locations, as aging may cause different areas of the building to respond differently to the same sealant product. Multiple tests comparing different surface preparation methods can help determine the best balance between efficiency and good sealant-substrate bond.

Laboratory testing may provide more in-depth and detailed information than does a field test. In the lab, it is possible to vary conditions for application and curing, such that a sealant product may be tested in many possible scenarios. The downside is that lab testing isn't done under actual field conditions, which may vary from those simulated in a laboratory setting. Plus, many manufacturers require adhesion tests performed on site, which means that lab testing would need to be done in addition to, not in lieu of, field testing.

Insufficient joint preparation can compromise sealant adhesion. Debris and residue must be cleaned prior to new sealant installation.

Sealant Joint Rehabilitation

Where feasible, sealant replacement projects should begin by resolving original design flaws in joint dimensions and spacing. Joint preparation should involve removal of existing sealant, dirt, and debris through the use of grinding, compressed air, or wire brushing, as appropriate. Non-porous substrates may be cleaned with solvents, using the two-rag method: one rag for solvent application, followed immediately by a second clean, lint-free rag to dry the surface.

Next, appropriate primer may be applied according to the manufacturer's recommendations. Surfaces should be primed *before* backer rods are inserted into the joint. The backer rod provides resistance to the pressure applied during tooling, helping to achieve the correct width-to-depth ratio and a smooth sealant surface. Typically composed of polyethylene or urethane foam, backer rods are categorized as *open-cell* or *closed-cell*. Open-cell backer rods allow air to circulate behind the sealant, permitting even curing; however, open-cell rods are not appropriate for horizontal or submerged joints, where they can absorb and retain water.

Other pitfalls to avoid include using sealant that has reached or exceeded its shelf life, storing sealant in a location subject to extreme temperatures, mixing multi-component sealants incorrectly, and applying irregular pressure and flow with the sealant gun. The number and variety of occasions for error in a sealant replacement project make it especially important to have a project team member tasked

(continued on page 8)

representative projects

Sealant Joint Rehabilitation

As specialists in building envelope rehabilitation, Hoffmann Architects has the experience to develop sealant replacement programs that go beyond re-caulking to address the underlying design, specification, and installation flaws that led to sealant failure. The result: sealant joints that are aesthetically appealing, long-lasting, and water-tight.

Hoffmann Architects' sealant joint rehabilitation experience includes:

TrizecHahn Corporation
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Panel/Window Sealant Replacement

Funger Hall
The George Washington University
Washington, DC
Concrete Panel and Sealant Rehabilitation

One Beacon Street
Boston, MA
Facade Sealant Rehabilitation

Bayer Corporation
Chemical Research Facility
West Haven, CT
Sealant Evaluation

World Trade Center
Baltimore, MD
Sealant Replacement Consultation

Ericsson (Telcordia Technologies)
Piscataway, NJ
Sealant Investigation

Sheraton Suites on the Hudson
Weehawken, NJ
Sealant Replacement Consultation

Marsh Inc. Headquarters
1166 Avenue of the Americas
New York, NY
Facade, Plaza, and Fountain Sealant Replacement

University of Connecticut Health Center in Farmington, Connecticut.
Facade Sealant Replacement.

Vornado/Charles E. Smith, Crystal City Office Complexes in Arlington, Virginia.
Sealant Remediation at Eleven Buildings.

Metropolitan Executive Towers
East Rutherford, NJ
Curtain Wall Sealant Replacement

Hyperion Software Headquarters
Stamford, CT
Sealant Failure Investigation

BMW of North America Headquarters
Woodcliff Lake, NJ
Parking Garage Rehabilitation

TIAA-CREF / CB Richard Ellis
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McLean, VA
Sealant Replacement Consultation

J.P. Morgan Chase Bank
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New York, NY
Facade Cleaning and Sealant Replacement

M&T Bank Headquarters
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with on-site quality control, to see that installation meets the manufacturer's warranty requirements for testing and inspection. If problems are identified straightaway, they may be rectified before it's too late.

Sealant Success

The limited lifespan of sealants means that they inevitably need to be replaced. Achieving the full expected service life of a sealant requires a combination of correct joint design, appropriate sealant selection, product performance testing, appropriate surface preparation, and conformance to manufacturers' guidelines and industry standards. A good reference is *ASTM C1193: Standard Guide for Use of Joint Sealants*, which provides in-depth information on joint design and sealant installation.

Sound sealant joints are necessary to a building's ability to resist water infiltration and respond to movement. Although they may seem to require little more than a shot from a caulk gun, sealant joints demand care and attention if the building envelope is to perform as intended.

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