Joint Sealants: Products & Application for the Natural Stone Industry

1.0 Introduction: Understanding some chemistry is important when selecting sealants for natural stone. This technical bulletin presents an overview of the design, use and application of joint sealants which are used in the natural stone industry. Discussed are various chemistries and other important considerations for selection of sealants for natural stone installations and the application of the sealant. The intention is to provide a source of information to better understand sealants and provide resources for further research into the industry. It is not intended to provide an inclusive discussion of the sealant industry.

2.0 Sealant Chemistry: Sealants used for joints in weathersealing applications can be generally separated into two distinct categories based on the chemistry functionality: inorganic and organic. In each of these two categories, further classification of sealants can yield multiple subsets based on curing mechanism, two-part vs. one-part formulation, etc. The general difference can be boiled down to the backbone polymers used as the building block for an elastomer sealant. For inorganic sealants, silicone polymers are the main building block for the resulting sealant elastomer represented by a long chain of Silicon-Oxygen bonds, or (–Si–O–Si–), which do not contain an organic or carbon molecule in the main chain length. Organic sealants are comprised of polymers with carbon-carbon or carbon-oxygen bonds and can be represented molecularly as (–C–C–) or (–C–C–O–).

2.1 Silicone Sealants: Silicone sealants were first introduced during the 1940’s. These were acid-cure compounds that released acetic acid, or vinegar, upon exposure to moisture. The common term for the acid cure system is acetoxy. Acetoxy sealants may not be the best choice for certain types of natural stone since many can be basic, or alkaline in nature. The resulting reaction between the acid by-product of curing and a basic stone can create a reactant which interferes with the sealant’s ability to adequately adhere with the substrate. In addition, aesthetics may be compromised due to discoloration thereby reducing effective service life (see Stain Potential, page 3). This is not to say that acetoxy sealants should not be used in applications with natural stone. Certain surface treatments or sealers may mitigate potential for interaction between the sealant and natural stone. Consult industry professionals and sealant manufacturers for recommendations based on compatibility concerns.

In response to the above concerns with acid curing sealants, neutral cure sealants were introduced in the early 70’s with additional innovation and new product research continuing through today. Neutral cure means that the by-product of cure behave neither as acid or base and are more “friendly” when in contact with stone that may be sensitive to those materials. Among the neutral cure sealants, there are several subsets of chemistries that deliver a neutral system. Each of these chemistries bring with them unique properties and performance characteristics that may be suitable for specific applications.

Silicone sealants, when properly designed and applied; provide a durable, long lasting joint seal that withstands the affects of sunlight, inclement weather, temperature extremes and...
dynamic moving conditions. These benefits are derived from inherent performance of the silicone’s chemistry.

The backbone of a silicone sealant is composed of a long chain of Silicon and Oxygen atoms, or (–Si–O–)ₙ, giving them unique properties in relation to other sealant chemistries. The following is a list of properties:

- Ultraviolet or UV light does not have sufficient energy to break or deteriorate the bond between the silicon and oxygen giving an inherent protection from sunlight.
- The bond angle between the silicon and oxygen atoms in the polymer backbone allows for high movement capability in a dynamic or working joint. The movement for specific silicone sealants can range from ±25% of the original joint width up to +100% to -50%.
- Silicone polymer has a low glass transition temperature ($T_g$)¹ allowing it to perform in a wide temperature range. Silicones do not significantly soften when exposed in high temperatures like the desert of Nevada or harden in colder climates like Northern Minnesota.
- Silicone polymers are hydrophobic or water repellant which indicates the lack of affinity for water in the liquid form; an important attribute for a material that is applied to prevent water infiltration into building facades.

Silicones have disadvantages which include the lack of ability to accept paint, soft surfaces prone to abrasion, some attract dirt and some formulations may contain plasticizers which can stain porous substrates.

2.2 Organic Sealants: The main organic sealants used in weatherproofing applications are generally designated by the following chemistry types: Butyl, Polysulfide, and Polyurethane.

Butyl sealants were widely used in the 1940’s since the key ingredients of butyl rubber, isoprene and isobutylene, were increasingly available. In comparison to performance of other available silicone and organic technologies, butyl sealants are not widely used currently in weatherproofing sealant joints because of lower movement capability, sensitivity to temperature and hardening, and severe strain potential based on the amount of plasticizer in the formulation. Butyl sealants do bring benefits of good water resistance, unprimed adhesion to metals and glass and low moisture vapor permeability. For this reason they are commonly used as a primary seal in insulating glass applications to prevent water infiltration into the air space as well as prevent gas leakage.

Polysulfide sealants were the next leap of technology in glazing applications. The polysulfide polymer is based on a polyether, or carbon-carbon-oxygen bond, with sulfur ends (S–S–C₂H₄–O–CH₂–O–C₂H₄). This formulation allows for greater movement (±25%) in the sealant and is an important characteristic for dynamic weatherseals. Other benefits include good resistance to aging and weathering and good adhesion to non-porous surfaces. On porous surfaces, a polysulfide may need a primer to establish proper adhesion. The disadvantage to polysulfide in a dynamic weatherproofing joint is a combination of compression set due to reasonable elastic recovery as well as hardening over time.

Polyurethane is the last chemistry set within the organic group. Polyurethanes are typically based on a polyether polymer chain that essentially performs as well or better than polysulfide in comparison to dynamic performance. Polyurethanes typically are more resilient to compression set in a moving joint in comparison to polysulfides. Benefits include good movement capability, good elastic recovery, paintability and resistance to abrasion or physical abuse. Disadvantages in-
clude sensitivity to temperature which can stiffen the sealant and increase stress within the joint at low temperatures and sensitivity to moisture that can attack the urethane bonds.

For all organic based materials, exposure to UV from natural sunlight can be a concern. The carbon-carbon or carbon-oxygen bond is sensitive to degradation from the energy inherent in UV radiation. Consult specific sealant manufacturers for better understanding of how UV from sunlight can affect sealant performance in context to the expected life of the sealant.

3.0 Sealant Properties

3.1 Movement Capability: Movement capability is an important performance characteristic as it defines the expected capability for a sealant to perform in dynamic joints. Movement capability is expressed in technical data sheets as ± xx% or designated to be a class xx sealant as defined by ASTM C920, Specification for Elastomeric Joint Sealants.

Understanding the actual movement expected in the joint as well as the direction of movement is critical in selecting the proper sealant for the application. Figure 1 illustrates common joint types based on the direction of movement. Static joints are widely accepted in the sealant to be less than 15% movement regardless of direction. Structural engineers provide the movement analysis for the sealant joint based on expansion and contraction due to temperature differential, live loads of buildings, or building sway. Because natural stones have varying degrees of composition, it is important to provide the proper coefficient of thermal expansion based on the stone specified for the application.

3.2 Adhesion: Sealants are no better than the substrates to which they adhere. If adhesion is not achieved, the value of using a silicone sealant to prevent air or water infiltration is not delivered. Sealant manufacturers typically supply testing services or experienced based recommendations for the proper sealant selection, cleaning methods to prepare the surface for adhesion and the need for primer to promote adhesion between sealant and substrate.

Field adhesion testing is also an important aspect of the use and application of sealants. Not only can it be used to determine proper sealant selection and surface preparation, it also provides a measure for the installation of the sealant during the project as a method of quality control. ASTM C1521, Standard Practice for Evaluating Adhesion of Installed Weatherproofing Sealant Joints, provides industry developed procedures for performing field adhesion tests. Sealant manufacturers provide an additional source for procedures in technical literature for performing tests specific to sealant type.

3.3 Stain Potential: Sealants may contain plasticizers or non-reactive fluids to provide flow characteristics for application of the sealant. These components are not generally bound into the final cured sealant elastomer and can migrate from the sealant. Because natural stones are porous, this migration can cause unsightly aesthetic issues by creating a “wet” look around the perimeter of contact of the sealant to the natural stone.

Sealant manufacturers typically perform testing to confirm the stain potential of sealant on specific types of natural stone as well as offer warranties.
for sealants to be non-staining. Generally the testing is performed according to ASTM C1248, *Test Method for Staining of Porous Substrate by Joint Sealants*.

Silane crosslinkers are used in all silicone sealants and the silicon-modified organic materials (polyethers and acrylics) that are used as sealants in the construction industry.

Hydrophobing effect

As the sealant is applied into a joint, there is the potential for the excess crosslinkers (added to ensure adequate shelf life) to migrate into the porous material and crosslink into a hydrophobic resin beneath the surface. This phenomenon does not always occur, but when it does, it can be attributed to the inherent nature of the necessary silane crosslinkers. Therefore, it cannot be guaranteed that this phenomenon will never occur with a specific porous substrate.

Currently, there is no predictable laboratory test method to evaluate the potential for hydrophobing. This is being discussed within industry organizations for development. The hydrophobing effect does not happen frequently, making it more difficult to study and understand for development of a reliable test methodology. Actual mock-up conditions for extended exposures are the most reliable techniques coupled with industry professionals and the sealant manufacturers’ experience with natural stone that may be sensitive to the effect. When there are concerns,
the potential for hydrophobing can be mitigated through the use of primers acting as a barrier for migration, the use of open cell backer rods that provide a less tortuous path than porous stone and other techniques.

5.0 Joint Design Consideration: The typical weatherproofing joint is shaped like an hourglass (see Figure 2 below). The hourglass shape allows for maximum wet-out at the interface of the substrate and sealant while minimizing the depth of joint in the middle. Less sealant in the middle decreases the stress generated by the sealant to mitigate over stressing substrates that may be weak and decreases the stress generated in the sealant to prevent rupture of the sealant internally.

![Optimum Sealant Profile](image)

**Figure 2: Optimum Sealant Profile**

The weatherseal joint should be a 2:1 dimension where the face of the joint is 2 times that of the middle. Joints above 1" may only need a maximum depth of ½" over the total width of the joint to prevent increase stress internally of the sealant or increased stress at the interface of the sealant/substrate.

Minimum depth of a joint should be ¼" to ensure proper adhesive bite formation. Joint openings should be greater than ¼" in width to allow for proper access in cleaning, priming (if needed), and installing the sealant.

Other joint geometries, such as cap beads, fillet beads, etc., also require a minimum ¼" bite on each substrate in moving joints. Smaller contact may be acceptable for static or non-moving joints depending on application. Consult industry standards and sealant manufacturers for recommendations.

When designing moving joints, the following points also need consideration:
- A minimum 1/4" (6.4 mm) joint width is recommended. Wider joints accommodate more movement than narrow joints.
- Three-sided adhesion limits the amount of movement that a joint can accept without inducing a tear. Three-sided adhesion can be eliminated by the addition of a bond breaker tape or backer rod. With three-sided adhesion, no more than ±15% movement can be accommodated.
- A properly designed moving joint with a 2:1 width to depth ratio will accommodate more movement than a thick joint (i.e., 1.5:1 or 1:1 ratio).
- Sealants are designed to deliver optimum performance when the joints are shaped like an hourglass and use the 2:1 ratio.
- As the sealant joint width becomes larger than 1" (25 mm), the depth should be held at approximately 3/8" to 1/2" (9 mm to 12 mm). Consult sealant manufacturers for specific design criteria for width to depth ration in consideration of type of sealant used.
- Joint widths up to 4" (100 mm) can be accommodated with certain sealants. Wide joints may require additional care and attention to detail to provide an aesthetically pleasing finish. Wider joints may be better accommodated by preformed silicone elastomer strips.
- For further information, consult ASTM C1472, *Standard Guide for Calculating Movement and Other Effects When Establishing Sealant Joint Width*. 

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6.0 Sealant Installation: There are five basic steps for proper joint preparation and sealant application:
1. Clean – Joint surfaces must be clean, dry, dust-free and frost-free.
2. Prime – If required, primer is applied to the clean surface(s).
3. Pack – Backer rod or bond breaker is applied as required.
4. Seal – Sealant is applied into the joint cavity.
5. Tool – Dry tooling techniques are used to create a flush joint and to make certain the sealant has the proper configuration and fully contacts the joint walls.

Building materials such as marble, granite, limestone and other stones that absorb liquid are considered porous substrates. Dusting alone may be sufficient cleaning for new porous substrates. Depending on the condition of the surface, porous substrates may require abrasion cleaning, solvent cleaning or both. Laitance and surface dirt must be completely removed. Water repellents and other types of surface treatments, protective coatings, and old sealant, all affect sealant adhesion. Removal of these treatments, coatings or sealants by abrasion cleaning may be required to obtain acceptable adhesion.

Abrasion cleaning involves grinding, saw cutting, sand or water blasting, mechanical abrading or a combination of these methods. Remaining dust and loose particles should be removed by dusting the surface with a stiff brush, vacuuming or blowing the joints with water and oil-free compressed air. Once the abraded surface is clean and dry, the sealant can be applied. If the surface is dirty, it must be solvent cleaned with the “two-cloth” method explained below. Some porous materials will trap solvents after cleaning or priming. One must allow this solvent to evaporate before sealant is applied.

7.0 “Two-Cloth” Cleaning Method: Clean, soft, absorbent, lint-free cloths must be used. The “two-cloth” cleaning method consists of a solvent wipe followed by a dry cloth wipe.
1. Thoroughly clean all surfaces of loose debris.
2. Pour or dispense an acceptable cleaning-grade solvent onto the cloth. A plastic (solvent resistant) squeeze bottle works best for organic cleaning solvents. Do not dip the cloth into the container of solvent, as this will contaminate the cleaning agent.
3. Wipe vigorously to remove contaminants. Check the cloth to see if it has picked up contaminants. Rotate the cloth to a clean area and re-wipe until no additional dirt is visible.
4. Immediately wipe the cleaned area with a separate clean, dry cloth.

8.0 Primer Application Procedure: Primers are generally applied with the following considerations:
1. Joint surfaces should be clean and dry. Apply masking tape to the surfaces next to the joint to keep excess primer and sealant away from areas where primer/sealant is not intended.
2. Pour some primer into a small, clean container, and replace and tighten the cap on the primer can. To prevent deterioration of the primer, do not pour more than a 10-minute supply into the container.
3. Depending on the substrate and job conditions, two different methods can be used to apply the primer.
   - The preferred application is to dip a clean, dry, lint-free cloth into the primer and gently wipe a thin film onto the surface.
   - For “hard-to-get-to” areas and rough surfaces, apply the primer in a thin film with a clean brush.
4. Allow the primer to dry until all the solvent evaporates.

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3 The accumulation of whitish, spongy particles on the surface of freshly placed concrete.
5. Inspect the surface for dryness. If too much primer has been applied, a powdery, chalky, dusty film will form on the surface. In this case, remove excess primer with a clean, dry, lint-free cloth or a non-metallic bristle brush before applying sealant.

6. The surface is now ready for application of the backer rod and sealant. Sealant must be applied the same day the surfaces are primed. Any surfaces primed but not sealed on the same day must be re-cleaned and re-primed before applying sealant to prevent accumulation of debris or contaminants that may interfere with the adhesion.

9.0 Backer Materials: A backer rod is the typical backer material for most weatherseal joints. The role of a backer rod is to allow a sealant to be installed and tooled to a proper joint profile. Once the sealant cures, the backer material must not restrict the movement of the sealant or cause 3-sided adhesion. To provide sufficient backpressure during sealant installation, the backer rod should be sized approximately 25% larger than the joint opening. Sizing differs among backer rod types; refer to the manufacturer’s recommendations.

Three common backer rod types are used with sealants:
1. Open-cell polyurethane
2. Closed-cell polyethylene
3. Non-gassing polyolefin

When selecting a backer rod, consider the following:
1. **Open-cell polyurethane** backer rod allows the sealant to cure through the backer rod which is beneficial when fast sealant cure is desired. Open-cell polyurethane backer rod can absorb water which may have a detrimental effect in certain joint types.
2. **Closed-cell polyethylene** backer rod may outgas if punctured during installation requiring a wait time of 20 minutes before sealant application.
3. Other back-up materials such as expanding foam tapes or glazing gaskets should be viewed or tested for compatibility prior to use.

4. When a backer rod cannot be positioned in a joint opening, a Teflon® or polyethylene tape should be used to prevent three-sided adhesion.

10.0 Conclusion: The best joint sealant for a given application is the sealant that performs for the desired period of time and satisfies all the requirements for its intended use. Sealant manufacturers can provide recommendations and/or testing to ensure compatibility the proper fit between sealant and stone.

11.0 Additional Resources:

**ASTM Standards**
- C 1518, Specification for Precured Elastomeric Silicone Joint Sealants
- C 1299, Guide for Use in Selection of Liquid-Applied Sealants
- C 1248, Standard Test Method for Staining of Porous Substrate by Joint Sealants
- C 1193, Guide for Use of Joint Sealants
- C 920, Specification for Elastomeric Joint Sealants
- C 794, Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants
- C 717, Terminology of Building Seals and Sealants

**Publications**
- *Sealants: The Professional’s Guide*, Sealant Waterproofing and Restoration Institute

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