

Specifying Joint Sealants For Concrete Repair

Type M, Grade P, Class 25, Use T,O— What Do Those Things Mean Anyway?

By Gail S. Kelley, P.E.

The evolution of curtain wall construction during the first half of the 20th century marked a major change in building design. Curtain walls have allowed both the architect and the structural engineer tremendous design freedom. They have also created problems, though—leakage through badly sealed joints can damage or destroy expensive interior finishes and office equipment. Joint sealants have become a major component in façade waterproofing; the development of the sealant industry has been largely driven by the need for materials that are able to create a flexible seal in joints that sustain considerable movement.

Leakage through building expansion and isolation joints is usually not as dramatic as façade leakage. Leakage through these joints is often into spaces such as parking facilities where there are no interior finishes. As a result, the leakage is allowed to continue, sometimes for years. By the time the leakage problems are addressed, there may be significant deterioration of both the concrete and the reinforcing steel.

Most concrete repair projects include sealant replacement. Unfortunately, the sealant work is often considered “incidental” to the concrete work. Specifiers sometimes copy specifications from other projects without verifying that the project requirements are the same (or that the specified products are still available). Alternatively, the specification section may simply be a copy of a manufacturer’s specification, with no consideration of the project requirements.

Sealants are as important in concrete repair work as they are in façade work. Using the wrong type of sealant or failing to install the sealant correctly can significantly shorten the life of a concrete repair. This is particularly true for post-tensioned structures because there are often stressing-end anchorages at joints.

Understanding sealant behavior requires more than just reading the manufacturer’s literature. As in all repair work, experience is essential. Such experience should include talking to installers to get feedback and information on new products as

well as information on how different products perform under certain conditions. In addition, specifiers need to be aware of any changes to products they specify. Even a minor change to the formulation of a product may have a significant impact on its properties.

Requirements For Joint Sealants

The most common requirement for joint sealants is that they be able to achieve “weathertightness.” In some applications, they may also be required to reduce sound transmission or prevent passage of air, hot gases, or flames. Other requirements that may influence sealant selection for exterior applications are resistance to ultraviolet (UV) light and air pollution, or acceptable performance in extreme temperatures. Sealant for interior applications may be required to resist mildew, cleaning agents, or exposure to aggressive chemicals. Sealants exposed to foot and vehicular traffic must be able to resist abrasion, tearing, puncturing, and other forms of damage caused by sharp objects such as spiked heels, pebbles, and debris. Hard (rigid) sealants have good resistance to this type of damage but their limited elasticity and movement capability restricts their usefulness in “moving joints” such as expansion joints.

Joint behavior is a prime consideration for sealant selection. In moving joints, the sealant will be exposed to stresses due to dimensional changes of the joint. These dimensional changes include contraction due to shrinkage and creep as well as expansion and contraction caused by temperature and moisture changes. In addition, external forces due to gravity, wind, impact, hydrostatic pressure, or earthquake loads may act indirectly by causing substrate movement or may act directly on joint sealants.

Joints can be either butt joints or lap joints. Most moving joints are butt joints—the members forming the joint butt up against each other. The primary stresses on the sealant in these joints are due to

the cyclical expansion and contraction of the substrate; the sealant is compressed and extended as the joint narrows and widens. In lap joints, one side of the joint extends over the other side; joint movement thus causes shearing stresses in the sealant. Shearing may occur in combination with expansion and contraction in both butt and lap joints, though.

Types Of Sealants

Most project specifications for government and institutional work require that sealants used in building joints comply with ASTM C 920, "Specification for Elastomeric Joint Sealants." Some specifiers also use ASTM C 920 for work on private projects.

An elastomer is a material with rubberlike properties; the term comes from the word "elastic" meaning the ability of the material to return to its original dimensions after being stretched, and "mer," which is a chemical term for molecule. By definition, rubber is a material that can be stretched to at least twice its original length and returns "with force" to its original length when released. Elastomers (synthetic rubbers) have significantly less movement capability than true rubbers—most elastomers have been specifically formulated to perform well under certain service conditions and this may affect their movement capability. The ability to elongate and recover (return to their original dimension when unloaded) is their dominant characteristic, however.

Elastomers, like all plastics, are composed of long chains of molecules. Their elastic properties are due to the fact that there is strong bonding between the molecules in each chain but only weak cross-linking between the chains. This weak cross-linking allows the chains to move relative to each other and results in "soft" materials that have a very low elastic modulus. (A material's elastic modulus indicates its resistance to deformation under load; a low-modulus material will deform more than a high-modulus material.) Once elastomers cure, though, their initial shape is set—they cannot be softened and reshaped without changing the chemistry of the material.

Although the 2001 edition of ASTM C 920 was revised to include solvent-release and water-release curing sealants, most sealants used in both new concrete construction and repair are chemically cured. Solvent-release curing joint sealants includes semi-elastomeric sealants such as those in which the base polymer is butyl or acrylic. These materials soften when heated and rehardens when cooled, without any change to their chemistry. Their rate of recovery (the return to their original dimension after being extended or compressed) is not as good as chemically curing products and they tend to have high shrinkage. Most have limited movement capabilities (typically less than 10%)

and poor elasticity at low temperatures. Because these products contain volatile organic compounds (VOCs), local regulations may prohibit their use.

Chemically Curing Sealants

Chemically curing materials can be either single-component or multicomponent. Single-component sealants cure by reaction with moisture and oxygen in the atmosphere. Their depth must be restricted to approximately 1/2 in. because of this dependency on moisture and oxygen. Multicomponent sealants cure by chemical reaction with a curing agent or catalyst; this allows for placement depths greater than 1/2 in. Multicomponent materials tend to have better movement capabilities than single-component materials. They are also recommended for joints that will be covered with a membrane or coating soon after the sealant is installed. Once single-component materials are covered and don't have access to atmospheric oxygen and moisture, their curing stops.

The base polymer of chemically curing elastomers is usually polysulfide, polyurethane, or silicone. Polysulfides were initially the most commonly used sealants but they are being replaced by lower-cost polyurethanes and silicones that have equal or better performance characteristics, including greater movement capabilities and better resistance to UV and ozone.

Polyurethanes are the most commonly used sealants for building joints—they adhere to most construction materials without a primer and are considered "user-friendly" by installers. Single-component polyurethanes are typically used for non-moving column-slab and wall-slab "caulk" joints. Multicomponent polyurethanes are generally used for expansion joints, particularly those subject to vehicle traffic, because they have good hardness, good tear resistance, excellent recovery, and a fairly fast cure.

Most sealants, including polysulfides and polyurethanes, are organics, which means they are based on carbon-hydrogen chains. Silicones, however, are non-organics composed of silicon-oxygen chains. As a result, silicones have somewhat different properties than other sealants. Silicone sealants typically have higher movement capabilities and deteriorate less with age than other sealants. They also have good high- and low-temperature resistance and low shrinkage. Many do not have good abrasion resistance, though, and are not recommended for traffic joints unless they can be well protected. In addition, silicones are not suitable for applications where they will be continuously immersed in liquids. The curing agent for some multicomponent silicone sealants is an acid—these sealants are not recommended for joint substrates such as marble, copper, portland cement based materials, or galvanized steel.

ASTM C 920 Classifications

ASTM C 920 classifies sealants according to Type, Grade, Class, and Use.

Type indicates whether products are single- or multicomponent.

- *Type S* (single-component) products are usually furnished in prepackaged cartridges.
- *Type M* (multicomponent) products are furnished in two or more parts that must be mixed at the job site. Multicomponent products include those with two components consisting of a base and a catalyst, and those with three components (base, catalyst, and pigment). In three-component products, the pigment is a required part of the formulation.

Grade defines the flow characteristics of the sealant.

- *Grade P* (pourable) products are self-leveling. They have sufficient flow to fill joints in horizontal surfaces and remain level and smooth at temperatures as low as 40 °F (5 °C).
- *Grade NS* (*nonsag*) products are used for joints in vertical surfaces and can also be used in applications such as traffic joints in sloping surfaces where a self-leveling sealant would flow downhill. They will not sag at temperatures between 40 and 122 °F (5 and 50 °C).

Class indicates the sealant's movement capacity when subjected to repeated cycles of joint expansion and contraction. There are five classes: Class 100/50, Class 50, Class 35, Class 25 and Class 12-1/2. The numbers indicate movement as a percentage of the width of the joint at the time the sealant is installed.

- A *Class 100/50* sealant is able to withstand a joint width increase of 100 % and a joint width decrease of 50%.
- *Classes 50, 35, 25* and *12-1/2* are able to withstand increases and decreases of 50, 35, 25 and 12-1/2%, respectively.

Sealants are sometimes described as high, medium, or low modulus. Sealant manufacturers disagree on how to define modulus characteristics and even when to measure the modulus, however. Consequently, the terms high, medium, and low modulus only have meaning when comparing different products from the same manufacturer. Because of this lack of consistency, sealants are typically referred to by movement class rather than modulus.

Most polysulfide and polyurethane sealants are *Class 25*—this has led to the rule of thumb that joint width should be at least four times the expected joint movement. *Classes 100/50, 50, and 35* were introduced in the 2001 edition of ASTM C 920 to cover some of the new silicone sealants that have been developed for façades.

ASTM C 920 includes three *Use* categories related to exposure and four *Use* categories related to the joint substrate. *Use* classifications related to exposure are:

- *Use T*—sealants designed for joints in surfaces subject to pedestrian and vehicular traffic.
- *Use NT*—sealants designed for nontraffic exposures.
- *Use I*—sealants designed for use in joints that will be continuously submerged in liquids. *Use I* sealants are rated as either Class 1 and 2 with Class 2 requiring satisfactory performance over a longer test period.

Use classifications related to joint substrates are *M, G, A, and O*.

- *Uses M, G, and A* refer to sealants that remain adhered to mortar (*M*), glass (*G*), and aluminum (*A*), when tested for cyclic movement and adhesion-in-peel. These designations refer to very specific materials, however. Mortar is portland cement mortar, glass is clear float glass, and aluminum is clear anodized aluminum.
- *Use O* refers to sealants for substrate materials other than *M, G, and A*.

Most sealants have more than one *Use* classification, for example: *Uses T, M, O*. Sealants may also be classified as both *T* and *NT*, meaning they are recommended for both traffic and nontraffic applications.

Specifying Sealants

In theory, it is possible to specify sealants for repair work solely by referencing ASTM C 920. If possible, however, it is better to specify the manufacturers and products. For many applications, the performance characteristics measured in ASTM C 920 do not adequately define the differences between products. Given the variety of materials and finishes involved in building construction, the specifier needs to verify that the sealant is appropriate for the actual joint substrates of the project. If both ASTM C 920 and specific products are referenced, it is important that the ASTM C 920 references be correct.

ASTM C 1299, "Guide for Use in Selection of Liquid-Applied Sealants," is useful for selecting sealants based on a comparative evaluation of their characteristics. The Sealant, Waterproofing, and Restoration Institute's (SWRI) *Sealants: The Professionals' Guide* is another good reference for sealant selection and installation, but not all manufacturers participate in the SWRI program. The fact that a manufacturer is not a member of SWRI does not necessarily mean they do not manufacture a quality product.

Sealant Failures

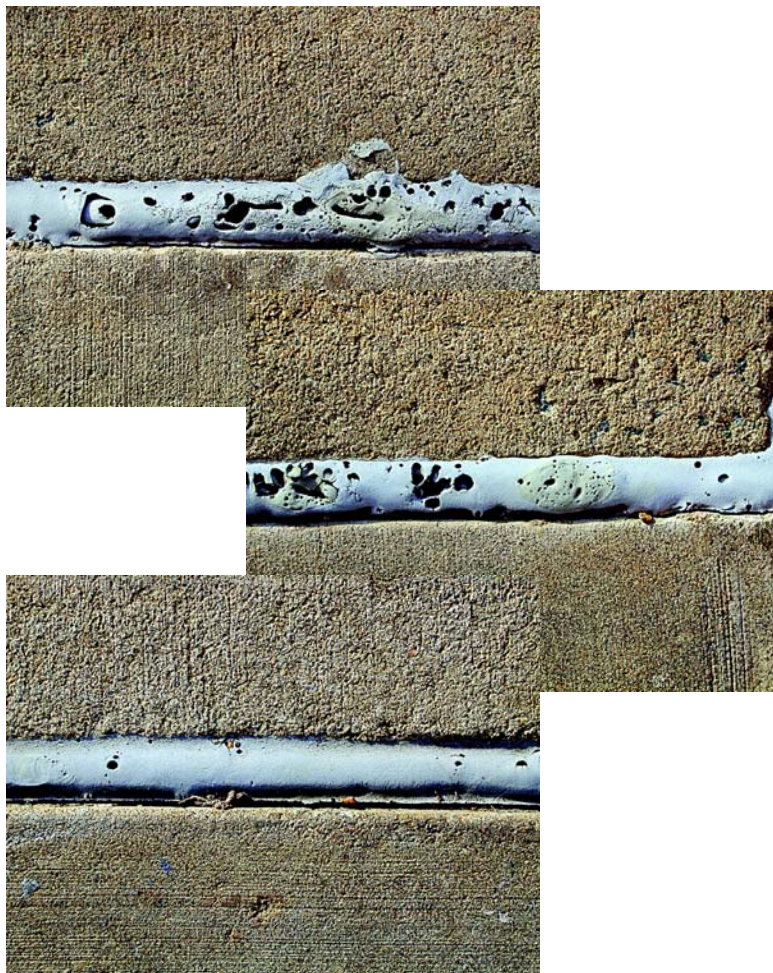
Evaluating joint sealant performance requires an understanding of the various modes of sealant failure. Joint sealants may not adhere to certain substrates or may react with them in a way that leads to eventual failure. Sealants may also stain certain substrates, particularly porous substrates such as marble and limestone that tend to absorb

oils, plasticizers, or other components migrating from the sealant. If incompatible sealants come into contact, this could also lead to sealant failure. If the sealant will need to be painted, the sealant manufacturer must verify that the sealant is compatible with the paint that will be used.

Sealant failure modes include:

- Adhesive failure—the sealant loses bond with joint substrates. Adhesive failure can be the result of sealant that is not designed for the substrate, sealant that is not properly mixed, or sealant hardening and loss of elasticity due to age or other causes. Adhesive failure can also be due to improper preparation of the joint substrates or joints that are too narrow with respect to their movement and the sealant movement capabilities.
- Cohesive failure—the sealant fails within itself. Some of the factors that cause adhesive failure can also cause cohesive failure.
- Intrusion failure—foreign matter becomes imbedded in the sealant and abrades it to an extent that results in cohesive failure during subsequent expansion and compression cycles.
- Spalling—a portion of the joint substrate pulls away with the sealant attached. Spalling is not always a sealant-induced failure, though; it may be a substrate failure. Spalling may indicate that the joint was sealed too early (while the concrete was still experiencing significant shrinkage) or that the joint was too narrow.
- Reversion—the sealant softens and loses its elasticity, simulating a return to its uncured state. There is no general agreement within the industry as to what causes reversion.
- Cracking (also called *alligatoring*)—normal, weather-induced deterioration of organic sealants. It can eventually lead to cohesive failure.
- Bubbling (caused by gas escaping from the sealant, backer rod, or substrate)—the sealant's integrity can be destroyed when the bubbles rupture.

Appearance-related failures including bloom, organic growth, color change, and chalking can also be a sign of sealant degradation.



Incomplete mixing of the sealant components resulted in severe bubbling as well as almost complete adhesion failure along the length of the joint

- Bloom occurs when fluids within the sealant migrate to the surface.
- Organic growth includes algae, mildew, and other microorganisms growing on the sealant's surface; the roots penetrate the sealant and may actually consume it.
- Color change can be the result of unstable pigments or an adverse reaction with another chemical.
- Chalking is when powder forms on the sealant's surface; it can indicate disintegration of the base polymer.

Primary Reasons Why Joint Sealants Fail

One of the primary reasons for premature sealant failure is insufficient movement capability of the sealant. If a sealant capable of 25% movement is used in a joint that experiences a 50% increase in width, there is likely to be a sealant failure. The other major factor in sealant failures is surface preparation, or lack thereof. In particular, joints in new construction or repair areas are sometime not prepared—it is assumed that because the concrete



If you have to pull weeds out of a joint, it is probably time to replace the sealant. (Cohesive failure with organic growth.)



Due to drainage problems and repeated sealant failures, there has been considerable leakage through this joint. The middle photo shows two of the six “barrel” anchors for the tendons in this band; the anchors bear against 1/2-in.-thick steel plates. Barrel anchors were often used at construction joints in early post-tensioning systems. Because the anchors are directly under the joint, leakage through badly sealed joints can cause severe deterioration. The bottom photo shows the six anchors after cleaning—all six strands had corroded completely through. The sealant failures may have been due to the fact that there were no dowels at the joint, thus, there was considerable movement due to traffic loads and thermal effects.

is “new,” it must be clean. Form release oils, curing compounds, and other contaminants usually find their way onto the sides of the joints, though. Unless they are removed, these contaminants will prevent the sealant from adhering properly.

Many sealants, particularly the polyurethanes, can be painted, but there may be problems if they are painted before they are fully cured. Single-component sealants generally require a seven-day cure before they are painted; multipart sealants need at least three days. Even with a proper cure, problems can still develop. Expansion joints are designed to expand and contract; if the paint used over the joints is not capable of this movement, it will crack and eventually peel off. Cracking and peeling paint can be unsightly and may be mistaken for a sealant failure.

It should be noted that even properly installed joint sealants have a finite life span—building maintenance and operation budgets should include an allowance for regular inspection, repair, and replacement of sealants.

Why Specifications Matter

The project specifications written by the owner’s consultant are the basis of the legal agreement between the owner and the contractor for the work of the project. It is thus essential that the project specifications clearly and accurately describe the work to be done. Specifications are particularly important in repair construction because materials must be appropriate for both the intended function and the existing conditions.

Specification writers sometimes appear to have a limited understanding of both joint sealants and the project requirements, however. The following is an excerpt from *Section 07920, Sealants and Caulking*, of the project specifications for a major repair to the plaza and parking levels of a post-tensioned office building.

2.01 SEALANTS

- A. Expansion Joint Sealant: a two-part, self-leveling, silicone sealant meeting ASTM C-920-94, Type S, Grade NS, Class 25, for specified uses. Acceptable products are as follows:
 1. Dow Corning 795; Manufactured by Dow Corning Corporation
- B. Garage Expansion Joint and Balcony Control Joint Sealant: a single component polyurethane sealant, meeting ASTM C920-97, Type S, Grade NS, Class 25, for specified uses. Acceptable products are as follows:
 1. Vulkem 322, Manufactured by Tremco Corporation
- C. Other Sealants: Sealant shall be suitable for intended application and compatible with all materials in which it comes in contact. Color to be selected by owner. Acceptable products are as follows:
 1. Dow Corning 790; Manufactured by Dow Corning Corporation

The specification contains a number of obvious errors. Paragraph A requires a two-part, self-leveling sealant that is “ASTM C 920-94, Type S, Grade NS.” Per ASTM C 920, a two-part, self-leveling sealant is “Type M, Grade P.” Paragraph B requires a Type S, Grade NS (single component, non-sag) product but lists a two-component, pourable product (although the correct name is Vulkem 322 DS). Paragraphs A and B refer to different versions of the ASTM specification. Paragraph C is completely meaningless.

Means and Methods

Well-written specifications are no guarantee that a project will be successful. On the other hand, poorly written specifications are usually a guarantee that there will be problems. On many projects, considerable emphasis is placed on the fact that “means and methods” are the responsibility of the contractor. This is true, and should be both well

understood and adhered to, but it should not be an excuse for a specification writer that has no understanding of the work. By and large, contractors and materials suppliers know how to do the work correctly, and try to do so in spite of what the project specifications might say or fail to say. Unless the project specifications accurately describe the work, however, it may be difficult to achieve the quality that the owner requires.

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ASTM Tests Required By ASTM C 920

ASTM C 920 includes a variety of tests to evaluate sealant performance. It should be noted that some of these tests only provide information that is important to the installer in terms of labor or material costs; they do not address in-place performance. Some tests such as the adhesion-in-peel test (ASTM C 794) have poor repeatability; it is questionable how reliable they are for predicting actual in-service performance. Similarly, some test methods evaluate joint-sealant performance under conditions that bear little resemblance to the conditions that the sealant will be exposed to.

Test methods that provide some indication of actual installed performance include:

- Adhesion and cohesion after cyclic movement (ASTM C 719). Movement capability is the amount of extension and compression that a sealant can sustain without failure. It is a plus and minus value calculated as a percentage of the joint width at the time of installation; this is the basis for the ASTM C 920 Class designation. Cured specimens are tested with specific joint substrates by subjecting them to cyclic movement after initially compressing them and immersing them in water.
- Adhesion is also measured by the adhesion-in-peel test (ASTM C 794). Strips of sealant are applied to materials representing joint substrates and cured, then the force required to peel the sealant from the substrate is measured. ASTM C 719 is more useful for judging adhesive capabilities of sealants during cyclic movement, however. The Canadian standard CGSB 37.58 M86, "Adhesion to Peel When Wet," is better than ASTM C 794 in terms of matching the actual conditions that the sealant will be exposed to.
- Hardness is measured by subjecting cured sealant specimens to an indenter and measuring the penetration (ASTM C 661). The results are reported as

Shore A hardness with a higher number indicating a harder material. To qualify for traffic use under ASTM C 920 requirements, the hardness must be not less than 25 and not more than 50. ASTM C 920 notes, however, that sealants with a hardness less than 25 may be used in traffic-bearing areas if recommended for use by the manufacturer. It also notes that hardness is not generally considered a measure of abrasion or wear resistance.

- Effects of accelerated weathering (ASTM C 793) are determined by exposing cured sealant specimens to 250 hours of UV radiation with intermittent water sprays in an accelerated weathering machine, then temperatures of $-15^{\circ}\text{F} \pm 3.6^{\circ}\text{F}$ ($-26^{\circ}\text{C} \pm 2^{\circ}\text{C}$) for 24 hours. After exposure, the specimen is bent around a mandrel and the amount of cracking before and after bending is reported. It is generally acknowledged that an exposure of 250 hours, even with accelerated aging exposures, is not sufficient to ensure long-term durability, however.
- Effects of heat aging (ASTM C 1246) are evaluated according to the percentage of weight loss and presence of cracking and chalking after being exposed to temperatures of $158^{\circ}\text{F} \pm 3.6^{\circ}\text{F}$ ($70^{\circ}\text{C} \pm 2^{\circ}\text{C}$) for 21 days.
- Porous substrate staining and color change probability (ASTM C 510) is evaluated by exposing sealant specimens to different exposure treatments. At the end of the 28-day exposure period, the width and depth of any stains are recorded.
- Durability of a sealant exposed to continuous immersion (ASTM C 1247) is evaluated by immersing test specimens in a hot liquid for six weeks, then subjecting them to three movement cycles. If the sealant does not fail cohesively or adhesively, it qualifies as a Use I, Class 1 sealant. If it does not fail after another four weeks of immersion, it qualifies as a Use I, Class 2 sealant.