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The Ins and Outs of Caulking

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Abstract

Effective water management involves understanding the roles of siding, trim, fenestration units, flashing, and (where appropriate) caulk seals and how these entities interface with each other. Where caulk seals are used, their geometry and dimensions are important to joint performance, as is the care with which they are executed. In selection of caulking material, consideration should be given to compatibility with substrates, to ambient conditions at application and during cure, and to the skill level of the applicator. Where and when caulk seals are used, they should not be assumed to remain functional indefinitely.

Keywords: caulk, sealant, water management, flashing

Contents

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The Ins and Outs of Caulking

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Introduction

Caulk is sometimes used in residential construction to inhibit rainwater intrusion where wall cladding interfaces with windows and doors (fenestration units) and is commonly used where utilities (such as pipes, vent hoods, and electrical conduit) penetrate the wall. Prior to development of modern caulks, caulk typically was not used at the interfaces of wood siding and fenestration units. Although not assumed to be watertight when subjected to windblown rain, these interfaces nevertheless usually did not leak noticeably. Fenestration units were designed to shed water at sills and drip it beyond the exterior of the cladding (siding) system. Siding pieces were tightly fitted to jamb casings (Figs. 1A, 1B) and were shingle-lapped with sills (Fig. 2). At window heads, siding pieces were shingle-lapped with either head flashing or drip cap (Fig. 3); in some cases both drip cap and head flashing were used.

Figure 1A—Painted redcedar bevel lap siding butted tightly to window jamb casing without caulk. Photograph taken summer 2005 on ranch-style home constructed in 1960.

In contemporary residential construction, windows may not have protruding sills that collect water and shed it to the exterior of the siding. Contemporary metal and vinyl siding systems are designed to allow for drainage of water that penetrates between the siding and fenestration units. These systems incorporate termination and transition accessories that work with concealed flexible flashing materials (installed around the perimeters of fenestration units); they are generally intended to function without caulk joints between siding and fenestration units or fenestration unit trim (Figs. 4A, 4B). Other contemporary cladding systems may, however, rely on caulk joints at cladding system–fenestration interfaces and cladding-to-trim joints (Fig. 5).

Figure 1B—Painted redcedar lap siding butting tightly against a window casing without caulk. Photograph taken summer 2005 on a single-story home built in 1940.

Caulk joints cannot be expected to remain functional indefinitely; leakage will eventually occur. Sealant joint failure can occur by adhesive failure between the caulk and either of the substrates between which a seal is desired. Cohesive failure or chemical degradation of the caulk can also cause sealant joints to fail.[1] Of these possible types of failure, adhesive failure between caulk and substrate is the most common failure mode. ASTM C 1193, *Standard Guide for Use of Joint Sealants* (ASTM 2005), provides extensive guidance for execution of sealant joints. The guide was developed for use in commercial construction, where caulking is a specialized trade. Many of the principles outlined in the

[1]An example of chemical degradation in service is “reversion,” which sometimes occurs with certain polyurethane sealants. Reversion is the term used when the cured sealant “reverts” to a tacky state; in extreme cases, reverted sealant can flow from joints under the influence of gravity.

Figure 2—Wood siding shingle-lapped with an outwardly sloped wood window sill without caulk. Photograph taken in summer 2005 on a 1½-story home constructed in 1916.

Figure 3—Wood drip cap, atop window head casing, installed in shingle-lap fashion with redcedar trim and without caulk. In this example, there is no metal head flashing over the wood drip cap and behind the siding. Water intrusion between the drip cap and the siding could be expected if this detail were exposed to significant wind-blown rain. A modest 0.3 m (12 in.) roof overhang on this single-story home evidently provided adequate shelter from wind-blown rain. This is the same window shown in Figure 1B.

Figure 4A—Vinyl siding terminating in a J-channel receptor along window jamb trim.

Figure 4B—Interface of vinyl siding J-channel receptor and aluminum window jamb trim. Outward thumb pressure against the J-channel reveals that there is no caulking between the J-channel and the jamb trim. This is consistent with installation guidance available from the trade association for vinyl siding. This installation was about a decade old when the photo was taken and had performed acceptably.

Figure 5—Joint between embossed oriented strand-board (OSB) lap siding and embossed OSB gable-rake trim. The siding is installed without a siding termination channel. The joint is gapped and sealed with caulk, as recommended by the siding manufacturer. Caulk seals were just under 4 years old when photo was taken and were apparently functional.

guide are, however, also applicable to sealant joints in residential construction.

Caulk or Sealant?

Modern caulks incorporate synthetic polymers. Higher performance caulks marketed for residential construction incorporate one of four different types of synthetic polymer: silicone, polyurethane, emulsified (latex) acrylic, or solvent-borne block copolymer. Of these, latex acrylic, silicone, and polyurethane caulks are widely used. Block copolymer caulks are relatively uncommon; they are specialty caulks, usually selected for their clarity, where this attribute is important. Each of the polymer types has its own particular (and in some cases, peculiar) advantages and disadvantages.

Caulks that meet the requirements of ASTM C 920, *Standard Specification for Elastomeric Joint Sealants*, are termed "sealants." ASTM C 920 was originally developed for sealants used in commercial construction; it covers a wide variety of sealants, some of which (such as polysulfides and two-component polyurethanes) are not used in residential construction. Conformance with C 920 requires, among other things, adequate performance in test procedures that evaluate adhesion (to specified substrates) and cohesion under cyclic movement. Standard C 920 also specifies resistance to cracking at elevated temperature, at cold temperature, and after exposure to ultraviolet radiation. Conformance with ASTM C 920 generally is an indication of superior performance, although a simple statement of conformance to the standard does not fully describe performance. The standard recognizes five different classes, categorized by the degree of movement between substrates that the sealant can tolerate. Classes range from a Class 100/50, indicating that adhesion and cohesion meet acceptance criteria at 100% elongation and at 50% compression, to a Class 12½, indicating that adhesion and cohesion meet acceptance criteria at 12.5% elongation and 12.5% compression.

ASTM C 920 (indirectly) specifies limits on maximum allowable shrinkage of sealant during extended cure. Latex acrylic caulks usually shrink enough during extended cure that they will not meet this particular requirement for conformance with C 920. Uncured latex acrylic sealant can, however, generally be applied successfully to cured sealant of the same type.

A wide variety of emulsified resin ("latex") caulk is available, ranging from low-cost products that may incorporate vinyl rather than acrylic polymers and that meet none of the performance requirements of C 920 to products that meet all except the shrinkage limitations of C 920 Class 25. Latex acrylic products are in many ways the easiest of the sealants to use. In residential building, where the knowledge and skill of applicators may not be well developed, latex acrylic sealants may provide performance as effectively as silicone or polyurethane sealants even though they do not match the performance of these (usually higher cost) sealants in controlled laboratory testing.

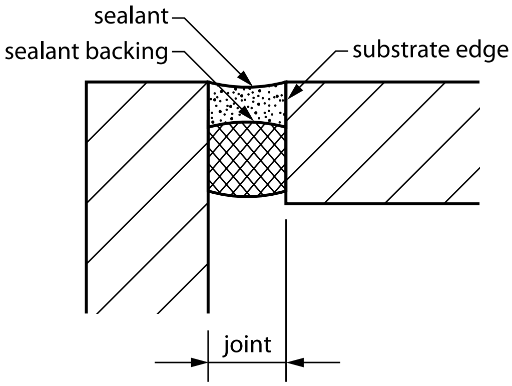
In this report, the terms "caulk" and "sealant" are used more or less interchangeably, as often occurs in the building industry, even though there is a rational basis for distinction between the terms. As indicated previously, the term "sealant" implies superior performance.

Substrate–Sealant Compatibility

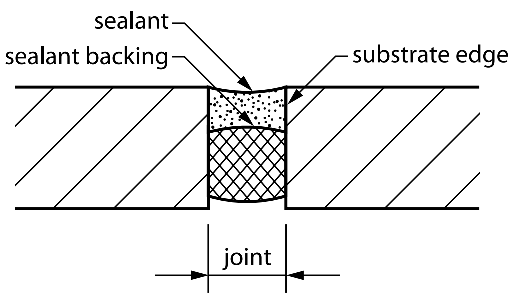
Compatibility between substrates and sealants involves two issues. The first is sealant adhesion to substrates (which may be dissimilar); the second is the potential for uncured sealant to damage the substrates (by chemical action of a component in the uncured sealant).

Silicone sealants are recognized as adhering well to most non-porous substrates. Their effective adhesion to porous substrates like wood or masonry may, however, require the use of primers. Polyurethane and latex acrylic sealants are generally recognized as adhering relatively well to porous substrates like wood and wood-based products without the use of primers. Sealant primers are rarely if ever available at hardware stores and home centers. A quality primer paint, suitable for the porous substrate, usually improves sealant adhesion. If end and edge cuts on siding or trim surfaces are primed before the siding or trim is installed, the priming is significantly more effective.

Chemical components of sealants with the potential to damage substrates are most commonly either organic solvents or acidic constituents. Organic solvents used in most sealants are not sufficiently aggressive to harm most substrates. The



a. face to edge



b. edge to edge

Figure 6—Cross-sectional sketches of butt sealant joints. Virtually identical sketches can be found in ASTM C 717-05, *Standard Terminology of Building Seals and Sealants.*

smell of vinegar in uncured silicone sealant indicates the presence of an acidic constituent. Most substrates are unaffected by such acidic-cure silicone sealants, but a few are. Installation instructions for components such as fenestration units may indicate if sealant use is recommended, and if so, what type of sealant to use. Use of a different type of sealant than recommended by the manufacturer may result in chemically induced damage to the component. Some silicone sealants are unsuitable for certain porous substrates because they can leach oily materials, resulting in staining.

Sealant Adhesion

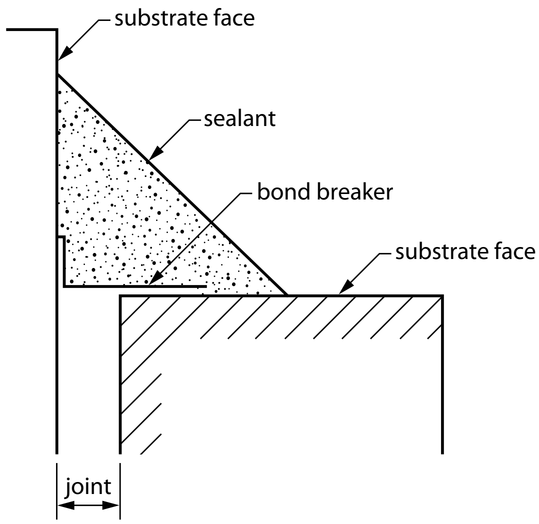
Nothing adheres well to a dirty surface. In addition, new and apparently clean metal components may have oils in their surfaces left from manufacturing processes. Likewise, the extrusions of vinyl, vinyl-clad wood, and wood–plastic composite windows may have residual extrusion die lubricants on their surfaces. Satisfactory sealant adhesion requires removal of such contaminants. Wiping with a clean rag moistened with mineral spirits is an effective method of removing surface oils and die lubricants. This can, however, pose health and fire risks if done carelessly, and residual mineral spirits that do not fully evaporate before caulk is applied may compromise adhesion. Substituting denatured alcohol for mineral spirits generally poses fewer health risks, and alcohol's relatively rapid evaporation rate is more likely to leave a clean dry surface. Organic solvents, while generally effective at removing organic surface contaminants such as oils, may not be compatible with all substrates; this is an additional reason that justifies caution in their use. Surfaces contaminated with dirt, airborne dust, and mud usually are most effectively cleaned with a well-rinsed water-wetted rag. Rinsing the rag in a detergent solution can aid in surface cleaning, but if this is done, residual detergent left on surfaces will interfere with caulk adhesion. If use of detergent solution is deemed necessary to obtain adequate surface cleaning, it must be followed by thorough rinsing with a water-wetted rag. Adequacy of rinsing can be difficult to ascertain; therefore use of water and a non-abrasive nylon cleaning pad should be attempted before resorting to use of detergent solution. Because porous surfaces are generally absorptive and thus difficult to adequately rinse, use of detergent solution on them as in preparation for caulking is not recommended.

At application, surfaces must also be free of ice or frost. At below-freezing temperatures, frost may accumulate on surfaces from an applicator's breath; this is among the reasons that manufacturers, as discussed below, commonly restrict application temperature.

Butt and Fillet Joints

ASTM Standard C 717, *Standard Terminology for Building Seals and Sealants*, defines butt sealant joints and fillet sealant joints. A butt sealant joint is a joint in which sealant is applied between two approximately parallel substrate surfaces that are either edge-to-edge or face-to-edge (Fig. 6). A fillet sealant joint is a joint in which sealant is applied over (not into) the intersection between surfaces that are approximately perpendicular to each other (Fig. 7). In a well-executed butt joint, the sealant does not adhere to any rigid material at the back of the joint. In a well-executed fillet sealant joint, the sealant is not adhered in the root of the joint. If sealant adhesion occurs at the back of a butt joint or in the root of a fillet joint, stress concentrations will occur in the sealant when there is differential movement between substrates. Joint failure will thus be likely, even when a high-performance sealant is used.

To prevent adhesion behind butt joints or in the roots of fillet joints, use non-rigid sealant backers or bond-breaker tapes. In commercial construction, caulking tradespersons are familiar with non-rigid sealant backers and bond-breaker tapes, and part of a tradesperson's skill involves his or her ability to fit joints with backer or bond breaker (or both) before application of sealant. Unfortunately, residential construction contractors and home owners rarely pay attention to prevention of three-sided adhesion in butt joints or to sealant adhesion at the roots of fillet joints. Hardware stores and home centers may sell sealant backer rods, but the



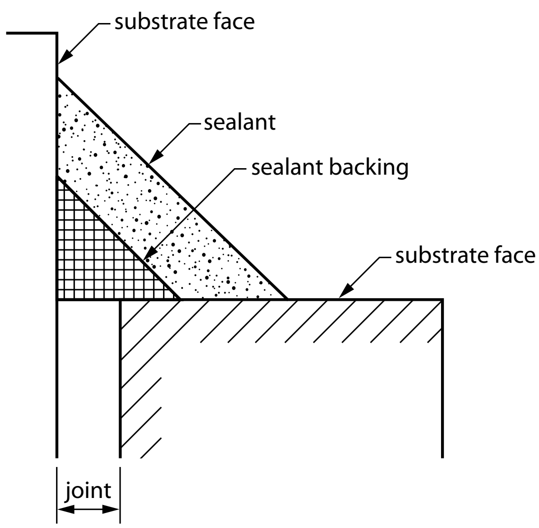


Figure 7—Cross-sectional sketches of fillet sealant joints. Virtually identical sketches can be found in ASTM C 717-05, *Standard Terminology of Building Seals and Sealants.*

variety of shapes and sizes is usually limited and virtually none of these retail businesses sell bond-breaker tape. An internet search will typically locate a handful of online merchants that market bond-breaker tapes to the general public. In retail home centers, backer rods are usually stocked with weatherstripping rather than with caulks and sealants.

No professional consensus exists on how long sealant joints in residential construction can be expected to remain functional. Professionals commonly believe, however, that the service life of residential sealant joints is usually shorter than 20 years. Manufacturers' warranties of multiple decades of sealant joint performance only provide for replacement of the caulking material. Cost of application labor is not covered by the warranties, nor is the cost of repairing damage sustained as a result of a failed sealant joint.

Figure 8—A perimeter sealant joint around a contemporary flanged window. The joint is of appropriate width at 6 mm (0.25 in.). The joint had been in service for roughly 3 years when photo was taken. Joint is mostly intact, but some adhesion failure is evident at lower right corner. As is common in residential construction, neither bond-breaker tape nor sealant backer was used. Joint failure is likely the result of three-sided adhesion, an unprimed siding edge, and other-than-ideal sealant width–depth ratio (sealant depth exceeding width).

Joint Dimensions Matter

In narrow joints, a given amount of differential movement between substrates translates into relatively large strain rates in the sealant. ASTM C 1193 makes no recognition of sealant joints narrower than 6 mm (0.25 in.). Figure 8 shows a 6-mm- (0.25-in.-) wide perimeter butt sealant joint around a residential window, which was in accord with the window manufacturer's installation instructions.

ASTM C 1193 states that acceptable sealant joint depth varies with joint width and sealant type. A generic rule for joints up to 13 mm (0.5 in.) wide is that joint depth should not exceed joint width. Minimum acceptable joint depth varies with the sealant type, and sealant manufacturers rarely if ever provide minimum depth recommendations to retail customers. With butt joints (Fig. 6), some minimum depth dimension at the substrate surfaces is necessary for adequate adhesion. The hourglass shape of the sealant cross section that can be seen in Figure 6 is considered desirable, as it provides the greatest possible adhesive-bond area at substrate surfaces and provides a region of relatively low stiffness at mid-width of the joint. Tooling of sealant (discussed in the following section) results in surface concavity that provides in part for the hourglass shape of the sealant cross section. With sealants that shrink during cure, concavity of the cured sealant joint surface is likely to be accentuated, and as a result, sealant depth at joint mid-width may be less than anticipated. When using sealants that shrink, making some trial joints to identify cured sealant depth at joint mid-width can be instructive.

Figure 9—Water staining on the back surface of hardboard siding on a test building. Leakage, although modest, occurred in 29 months of service and was determined to be through sealant joints. The sealant used in this installation met the requirements of ASTM C 920. None of the joints showed outward indication of failure. Subsequent laboratory testing indicated that the window unit, although not of the highest quality, was not the leak source. Sealant joints were a combination of bedded, butt, and fillet. At fillet joints, sealant adhesion at joint root was a likely contributor to failure. The building was in Florida where conditions at joint installation were hot and humid. These conditions would accelerate cure of the polyurethane sealant used. "Skinning" of the sealant before tooling was therefore also a plausible contributor to joint failure.

Tooling Helps Adhesion to Substrates

Adhesion to substrates is improved by tooling the sealant before it cures, because tooling assures uniform sealant contact with each of the substrates and works air bubbles from the sealant. Tooling usually results in a more aesthetically pleasing joint as well. In residential construction, sealant tooling is most commonly done with a finger, although use of a tooling device, such as a plastic spoon, is usually more satisfactory. Professional caulkers in commercial construction commonly fabricate their own tooling sticks and spoons. Emulsion acrylic sealants are the easiest to tool. Water is usually used as a tooling liquid (lubricant), and excessive adhesion to the wetted tooling device is rarely a problem. Polyurethane sealants often adhere mightily to tooling devices and thus usually require a lubricant on the tooling device. Some manufacturers of polyurethane sealants allow water or soap solution for tooling; others prescribe proprietary tooling lubricants. Silicone sealant manufacturers usually recommend dry tooling, although some may recommend a tooling lubricant. With some sealants, a tooling lubricant requires that the joint be completely filled prior to tooling. Lubricant on the surface of just-tooled sealant or on substrate surfaces may interfere with sealant cohesion or adhesion, respectively, if additional sealant is placed in the joint. Because latex acrylic sealants use water as both a suspension agent and a tooling lubricant, they are relatively immune to this problem. Experienced professional tradespersons rarely try to tool underfilled joints. In contrast, relatively inexperienced homeowners can reasonably be expected to sometimes make (and have to correct for) this error.

As indicated above, the purpose of tooling is to improve adhesion between the sealant and the sides of the joint. Tooling will coincidentally push sealant back into the joint. One of the functions of backing material is to prevent excessive depth of sealant in tooled joints.

Application Conditions

The range of acceptable application temperatures will be indicated by the sealant manufacturer. Emulsion ("latex") sealants cannot be applied below about 4.4°C (40°F). Silicone sealants typically have the widest acceptable range of application temperatures. Surface frost, however, remains a concern when temperature at application is below freezing. High temperatures will accelerate cure time. In some cases acceleration can be excessive, and adhesion to substrates will be compromised if the sealant "skins" before tooling can be accomplished.

Sealant should not be applied during or immediately after a rain. Freshly installed joints usually can withstand modest rain exposure, provided that the sealant has first "skinned" and provided that raindrops do not forcibly impact the sealant. Latex sealants are more likely to be deformed by rain exposure shortly after installation than are other sealant types. It is good practice to refrain from installing sealant joints if there is a threat of rain within 3 to 6 h. The acceptable time window will depend on ambient temperature and sealant type.

Shelf Life

Do not use caulk that has been stored for excessive periods. The caulk manufacturer may indicate shelf life on the product packaging. If it is difficult to force the caulk from the tube at normal temperatures, the shelf life has probably been exceeded. However, easy dispensing of caulk from the tube does not necessarily indicate product freshness. Some caulks that have exceeded their shelf life may be pumped easily from the tube but will fail to cure. Latex caulk that has been frozen in storage should be discarded.

Sealant Is Not a Substitute for Flashing

Modern sealants are capable of impressive performance in controlled laboratory testing and also in well-executed joints on buildings. As indicated previously, however, sealant joints in residential construction are usually executed by individuals with limited training and cannot be expected to

Figure 10—Metal Z-flashing at a horizontal joint in plywood panel siding. The second-story (upper) plywood panels should have been installed approximately 3 mm (1/8 in.) higher than in this installation. This would have provided more adequate drainage space between their lower edges and the horizontal leg of the Z-flashing (a paint bridge between the siding and the Z-flashing can be seen at the left-most groove in the photo). Well executed Z-flashing (without caulk) has proven effective at joints like the one shown here.

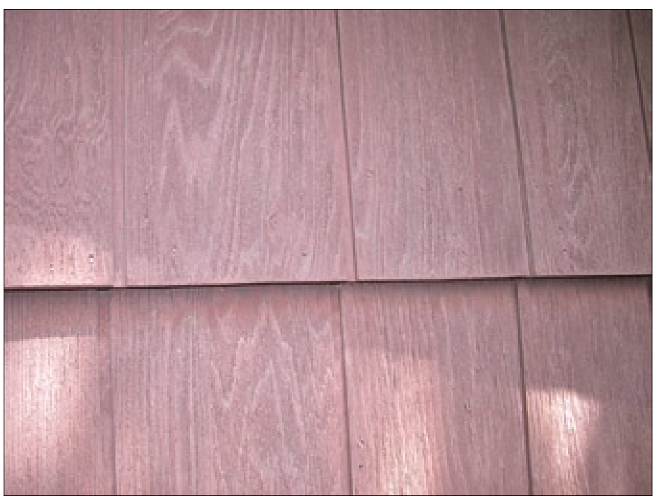


Figure 11—A shingle lap horizontal joint in plywood panel siding. At the time this photo was taken, the joint shown had performed adequately for in excess of four decades with no maintenance.

Figure 12—Transition between a contemporary finned window (below) and OSB horizontal lap siding (above). The window shown has been field-mulled (multiple units joined side-to-side). A metal head flashing is used that shingle-laps behind the siding above and covers the end of the mull cap. Caulk is not used between the head flashing and the siding, as it would block drainage off the flashing.

function indefinitely. Sealant joint failure can occur without obvious indication (Fig. 9).

Sealant joints should thus not be considered as acceptable substitutes for formed metal flashing. Well-executed formed metal flashing makes use of an exceptionally dependable force of nature: gravity. Water management by drainage is a time-proven strategy in the construction of wood buildings. For example, at horizontal joints in plywood panel siding, metal Z-flashing (Fig. 10) or shingle-lap joints (Fig. 11) are effective; sealant joints are not an acceptable substitute. Where there are drainage paths, it is important that caulk, if used, not block them (Figs. 12, 13A, 13B).

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Figure 13A—A failed fillet caulk joint between the ribbed aluminum sill and the pine jamb and jamb casing of a contemporary exterior door. The ribs retard drainage off the aluminum sill. The short length of fillet that runs parallel to the ribs also retards sill drainage and does so at a critical location.

Figure 13B—Extensive jamb decay in a contemporary exterior entry door. The decay was in all likelihood exacerbated by the short length of fillet joint that blocked drainage at the outside lower edge of the jamb.