



# **SHEAR DOMINANCE**

UNDERSTANDING THE ROLE OF  
ADHESIVE SHEAR STRENGTH IN LONG-TERM  
BUILDING ENVELOPE RESILIENCE

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## ENVIRONMENTAL FACTORS THAT IMPACT BUILDINGS

Cataclysmic events like earthquakes and hurricanes can cause sudden shifts or movements in structural components of buildings. Beyond these abrupt, extreme movements, residential and commercial structures experience much smaller, more subtle types of movement all the time. Annual weather patterns and seasonal changes that vary depending on climate zone impact the moisture content of building materials differently depending on the type of material they are made from. Shifting soil and other foundation-related issues can cause parts of buildings to settle at different rates. The impacts of changes, in temperature, moisture and even chemicals can cause construction materials to expand and contract at varying rates according to the materials' ability to withstand these factors.

Everything from geographic location and elevation to season, wind and humidity impacts the built environment. Any given day's ambient outdoor temperature can increase by 20 to 30 degrees from morning to evening,<sup>1</sup> only to drop back down overnight. Exposure to sunlight is also a vital temperature consideration—think of a building's southwest-facing wall on a 90 F (32 C) day. Combining the heat of the ambient temperature with that provided by the sun could bring the wall's temperature up to 150 F to 160 F (66 C to 71 C), often for several hours.

In addition to temperature fluctuations, some areas experience drastic seasonal changes, with prolonged cold temperatures during the winter and high heat and humidity in the summer. Furthermore, according to the U.S. Environmental Protection Agency (EPA), extreme weather events such as heat waves and tropical cyclones are becoming more common. Coincidentally while some areas are increasingly experiencing higher and sometimes sudden, heavy precipitation levels, others are seeing more drought conditions.<sup>2</sup> Architects, contractors and construction material producers must take all of these interrelated issues into consideration to ensure the long-term integrity of the structures they produce.

## WEATHER AND THE BUILDING ENVELOPE

Construction materials like wood and concrete typically expand with higher temperatures and humidity and contract in cooler, dryer environments. Design elements such as expansion joints for concrete and flexible anchors for structural elements are used to offset these environment-driven micromovements to ensure their durability. Similarly, it is vital to accommodate for subtle movements within the building envelope system.

The role of some flashing and seam sealing products has expanded in recent years. These products are commonly referred to as flashing tapes in the residential construction industry and self-adhering membranes or self-adhering flashing in the commercial sector. Historically, seam tape was used on weather-resistant barriers (WRBs, also known as housewrap) to ensure a consistent seal between edges and to prevent the WRB from detaching in harsh environmental conditions such as wind or heavy rain. With the introduction of pre-coated (aka factory laminated) oriented strand board (OSB) sheathing and the expanding use of rigid foam insulation on the outside of buildings, high-performance tapes are now needed to seal the seams in order to protect the structure.

Seam sealing tapes are considered part of the enclosure system; they are required by the manufacturers of the sheathing and insulation products and are needed for the structure to meet specific building codes (e.g. those focused on air and water leakage requirements). Flashing tapes are also used around fenestration elements such as windows and doors, pipe penetrations, dryer vents and other openings to protect the structure from moisture and air.

If these flashing/seaming products lose pliability or strength over time, they will not be able to adjust to the structure's constant movements. This leaves them prone to failure, which can lead to structural damage and reduce the effectiveness of the building envelope, increasing the potential for liability and extensive rework.

A common metric for evaluating the effectiveness of flashing/seaming tapes and membranes is peel strength, which is determined by measuring the amount of force required to remove a tape from the substrate. Since peel strength illustrates a tape's ability to adhere to a surface, it is highly relevant to the installation process. However, it doesn't necessarily reflect the tape's long-term strength and resilience against the slowly evolving movements that buildings continually experience over time.

In contrast, shear strength is a reflection of the tape's cohesive strength against both push and pull forces. Shear strength determines the tape's ability to hold itself together and resist delaminating as wind and temperature fluctuations influence the building's component movements over time. To better understand the difference between peel and shear strength, it is important to explore the properties of cohesion and adhesion.

## COHESION VS. ADHESION

Generally speaking, cohesion refers to a material's internal strength, while adhesion reflects that material's ability to adhere to other materials. Materials simultaneously feature varying degrees of both of these properties.

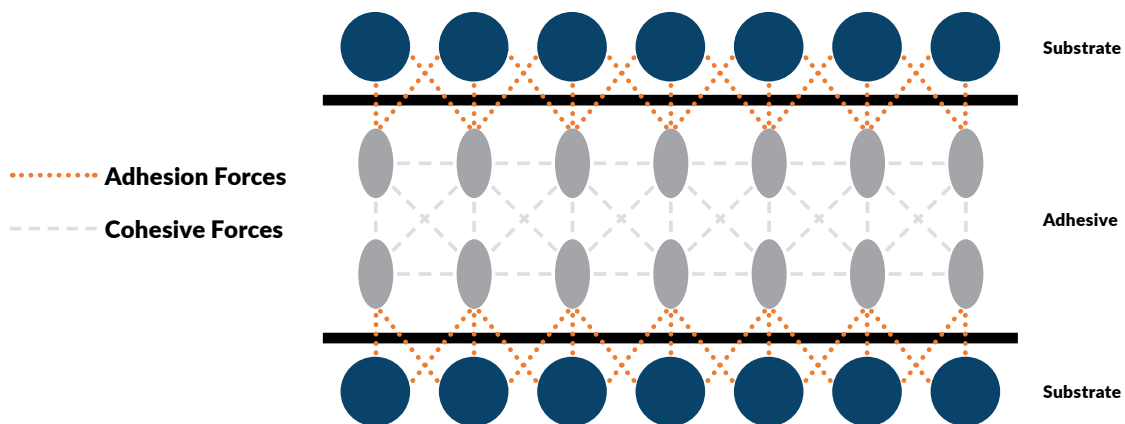
In water, for example, cohesion results in the water molecules being attracted to and joined to each other. Cohesion is the reason we have seas and oceans, puddles and glasses of water, instead of vast amounts of individual, separate water molecules. Conversely, the phenomenon of raindrops on a windowpane is the result of adhesion. The water molecules are also attracted to the glass and adhere to its surface.

In terms of adhesives, The Adhesive and Sealant Council explains cohesion and adhesion as follows:

"Cohesion is defined as the internal strength of an adhesive as a result of a variety of interactions within the adhesive. Adhesion is the bonding of one material to another, namely an adhesive to a substrate, due to a variety of possible interactions."<sup>3</sup>

Figure 1 illustrates how cohesion and adhesion work together in an adhesive product. As shown, cohesive forces operate within the adhesive so it is able to hold itself together. Alternatively—and simultaneously—adhesion forces enable the adhesive to remain bonded to the substrate.

**Figure 1. Cohesion and adhesion together determine the overall effectiveness of an adhesive.**



Therefore, when considering adhesive products for building envelope applications, it is crucial to evaluate the combined forces of cohesion and adhesion.

For example, one flashing/seaming tape may feature good adhesive strength. This translates to strong peel strength, reflected in the tape's ability to adhere to substrates like exterior glass-faced gypsum, plywood or OSB. That same tape may suffer from cohesive limitations, however, resulting in its inability to retain its integrity under certain environmental conditions or long periods of time.

The ideal flashing/seaming product features a balance of these two properties: adhesion (peel strength) that ensures the tape's ability to bond to construction substrates, along with the required cohesion (shear strength) to remain intact and effective under various environmental conditions for long-term use.

Unfortunately, not all adhesives are capable of providing this balance of properties.

# THE IMPORTANCE OF CHEMISTRY

Adhesives are typically grouped according to their chemical makeup. The three types of adhesive chemistries generally used for flashing/seaming applications include: rubberized asphalt, synthetic rubbers (elastomers) and acrylics. These adhesive chemistries are not interchangeable. Care must be taken to evaluate the overall balance of properties in order to ensure the desired results.

## Rubberized Asphalt

Rubberized asphalt, also sometimes referred to as bitumen, is produced by combining solvent-based styrene-butadiene-styrene (a synthetic rubber also known as SBS) with asphalt. The addition of SBS improves the processing and durability of the asphalt while also making it flexible.

Though it has been used for decades in building envelope applications and represents an inexpensive product on a pound-for-pound basis, rubberized asphalt has numerous limitations. In addition to various environmental concerns, the volatile organic compounds (VOCs) contained in rubberized asphalt lead to issues with durability and compatibility. As the VOCs off-gas, the adhesive dries out over time, losing its pliability and flexibility. This brittleness can cause building envelope failures when rubberized asphalt is used on building components that are prone to movement. Flashing/seaming products based on rubberized asphalt are not able to adjust to this movement over time and, as a result, lose their effectiveness.

The VOCs and solvents in rubberized asphalt can also react negatively with other materials used in the structure's construction. Materials such as caulking, sealants and vinyl window flanges often contain solvents and other chemicals that are incompatible with rubberized asphalt. These materials degrade when they come into contact with each other, causing not only reduced adhesive effectiveness, but also an unsightly and even damaging mess that could lead to litigation.

The environmental considerations surrounding the solvents and VOCs in rubberized asphalt are significant. Solvents are often toxic and must be stored, handled and disposed of with extreme care. In addition, off-gassing VOCs contribute to ground-level ozone formation and can negatively impact air quality for the construction crew and the building's eventual inhabitants. These factors make them problematic for projects seeking Leadership in Energy and Environmental Design (LEED) or similar sustainability-related certifications.

The limited operating temperature range for rubberized asphalt is another major drawback for its use in flashing/seaming applications. Rubberized asphalt adhesives have low adhesive strength below 40 F (4 C), which tends to lead to a shorter building season for those in cooler climates. In addition, these adhesives begin to soften between 135 F (57 C) and 180 F (82 C), which can result in a messy and time-consuming installation process, as well as performance issues in hotter climates or situations where the adhesives are

subjected to direct, prolonged sunlight. So-called high-temperature rubberized asphalts can be specially formulated for environments up to 240 F (116 C), but their adhesion capabilities are not as robust and their performance suffers at low temperatures.

Critically, rubberized asphalts can struggle to bond to textured substrates such as OSB and concrete. Primer is often needed to achieve a full bond in these situations, which results in additional labor hours while also introducing installation inconsistencies due to climatic influences on drying times. And as time is money in the construction industry, there's a tendency to speed up installation processes—but if installation moves too quickly and proceeds before the primer is fully dry, it can lead to reduced adhesive effectiveness and even potential failure.

## Synthetic Rubbers

Representing an improvement over rubberized asphalt, synthetic rubbers are generally produced in two forms: butyl rubber and block copolymers. Both types are typically blended with tackifying oils or other rubbers to achieve the desired performance.

A copolymer of isobutylene with isoprene, butyl rubber tends to be more expensive than its block copolymer counterpart. Often called hot melt rubbers, block copolymers are generally blends of SBS, styrene-butadiene rubber (SBR) and styrene-isoprene rubbers.

While both types of synthetic rubbers offer improved performance over rubberized asphalt, they come at a higher cost. Their main advantage is that they don't include solvents or VOCs and thus avoid the attending compatibility and environmental issues.

These types of adhesives also operate effectively at a wider temperature range than rubberized asphalt. Many butyl rubber-based adhesives bond well from 30 F (-1 C) to 200 F (93 C), while some butyls and block copolymers can go as low as 0 F (-18 C). These adhesives maintain their flexibility in cold weather, though they often require primer to be used during installation in colder temperatures.

Lack of durability is the main downfall of synthetic rubbers. The inclusion of tackifiers can be problematic, as the tackifiers migrate over time and negatively impact the adhesives' long-term performance. In addition, block copolymers have poor ultraviolet (UV) resistance. Both types can degrade with continued exposure to high heat and chemicals. They are also susceptible to oxidation and may darken or discolor.

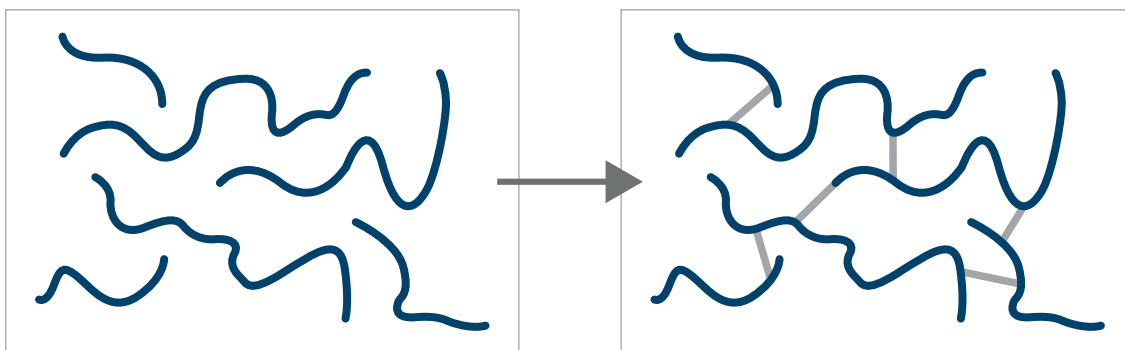


## Acrylics

Acrylic adhesives provide the most desirable balance of properties for use in flashing/seaming and other building envelope products. These resin-based adhesives, comprised of acrylic or methyl acrylic polymers, can be produced in liquid (with water or solvents) or in formulations with 100% solids that have no solvents.

Acrylic adhesives truly dominate in terms of shear strength as a result of a process known as crosslinking, which occurs as the adhesives cure. During the crosslinking process, covalent bonds are formed that hold portions of the polymer chains together (see Figure 2).

**Figure 2. Polymer chains are bound together during the crosslinking process, resulting in a stronger, more durable adhesive bond.**



The highly crosslinked polymer chains in acrylic adhesives create extremely strong molecular bonds that are stable against UV light, even at high temperatures. As a result, acrylic adhesives do not dry out and break down like rubberized asphalt and synthetic rubbers when exposed to prolonged sunlight, fluctuating temperatures and harsh conditions. This translates to long-lasting cohesive strength and high shear performance that softer adhesives like rubberized asphalt and synthetic rubbers cannot attain.

Advanced acrylic adhesives are produced from highly polar functional monomers. These functional monomers allow the acrylic adhesives to have a high affinity for adhering to a variety of substrates—including textured surfaces and those with low surface energy—without the need for primer. Though it can take time (24 to 72 hours) for acrylic adhesives to fully adhere to a low surface energy substrate, their unique flow properties enable the adhesives to flow into surface inconsistencies and produce permanent bonds.

Another key benefit of acrylic adhesives is their broad operating temperature range. These formulations can effectively and consistently adhere from 0 F (-18 C) to over 200 F (93 C). As a result, one flashing/seaming product can be effective for use in a wide range of climates and weather conditions, simplifying both the purchasing process and product storage requirements. In addition, the building season can be extended much longer into the colder months, and issues will not arise due to extended exposure to high temperatures or direct sunlight.

## PUTTING ACRYLIC ADHESIVES TO THE TEST

As noted earlier, the building envelope products that are attached to a structure are subjected to various forces that stress adhesive bonds as materials slowly move as the structure shifts due to environmental changes. In contrast to peel testing, which is conducted with force applied at an angle (typically 90 or 180 degrees) in order to measure how strong the bond is between adhesive and substrate, shear testing is performed in a parallel direction. The results illustrate the adhesive's ability to withstand the slow, sliding forces of the shifting structure.

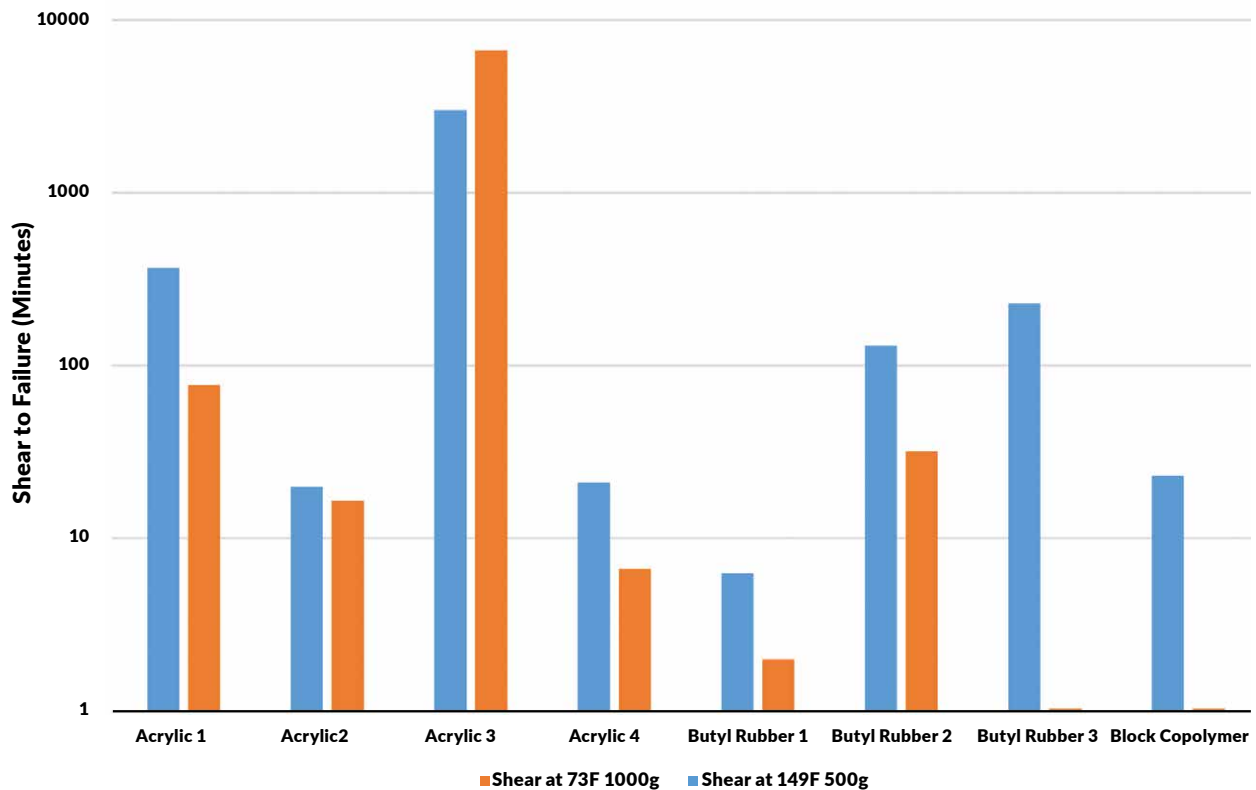
### Shear Performance

During tests conducted according to ASTM D3654 (Standard Test Method for Shear Adhesion of Pressure-Sensitive Tapes), a weight is attached to a substrate that is held in a vertical orientation. It is possible to reflect various application settings by varying the amount of weight used, as well as the temperature under which the testing is conducted. After each tape is applied to the substrate with consistent pressure and subjected to the desired parameters, the length of time until its adhesive fails is measured. The longer the adhesive is able to endure the test, the better its shear strength is considered to be under those parameters.

Studies were conducted to evaluate the shear performance of acrylic adhesives compared to synthetic rubber adhesives. One set of tests was run at room temperature (73 F/23 C) with 1,000-gram weights attached to the substrates. This heavy weight was used to represent the strong pulling and stretching forces that the tapes may encounter during application as installers work to contour the tapes to hard corners.

As shown in Figure 3, the acrylic-based tapes largely outperformed the synthetic rubbers. The results were even more definitive in a second series of tests run at 149 F (65 C) using 500-gram weights. At this high temperature—similar to what a southwest-facing wall might absorb on a hot, sunny day—two of the synthetic rubbers failed immediately. The others were unmatched by the superior shear strength of the acrylic adhesives.

**Figure 3. Shear performance comparison of acrylic adhesives vs. synthetic rubbers.**



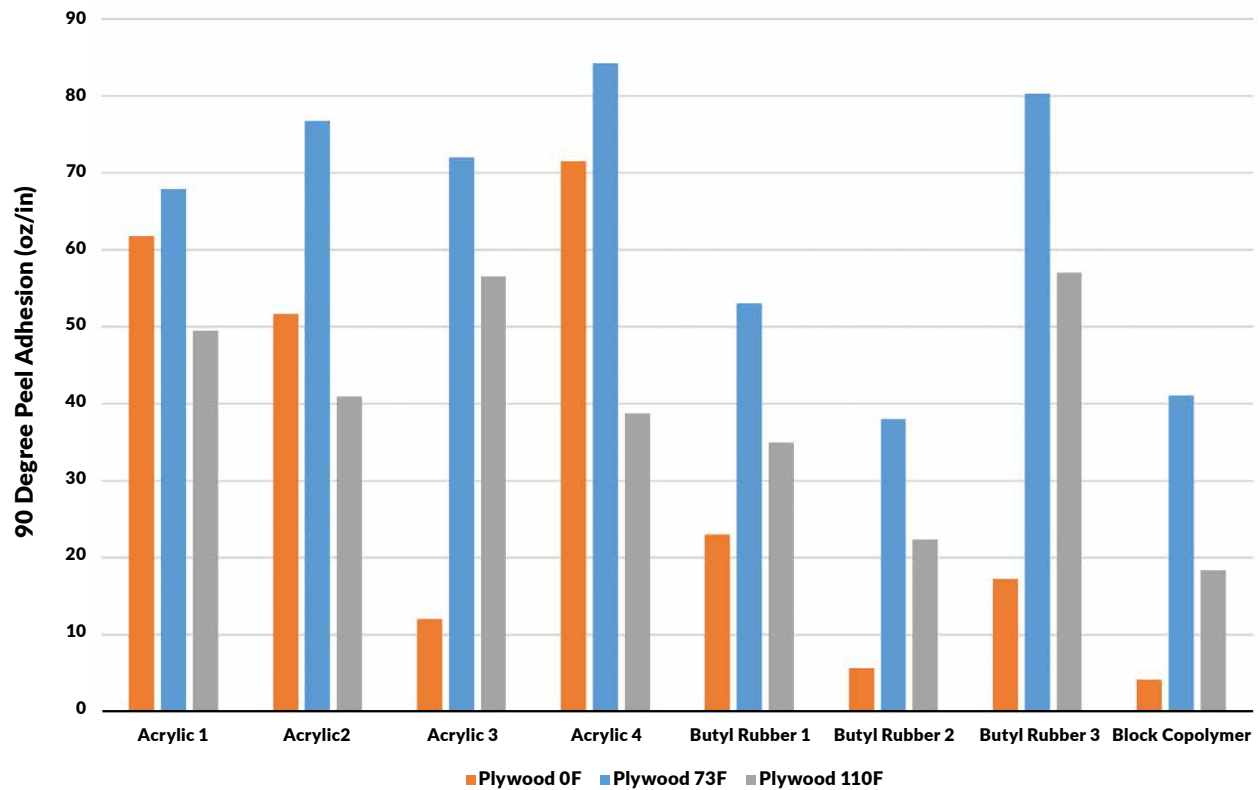
## Peel Performance

To illustrate that these acrylic adhesives don't sacrifice adhesive strength in favor of cohesion, a series of peel tests was also conducted. ASTM D3330 (Standard Test Method for Peel Adhesion of Pressure-Sensitive Tape) is a common testing standard used to determine the adhesive strength of tapes. ASTM D3330-F, in particular, measures the adhesive strength of a single-coated tape that is applied to a substrate and peeled at a 90-degree angle.

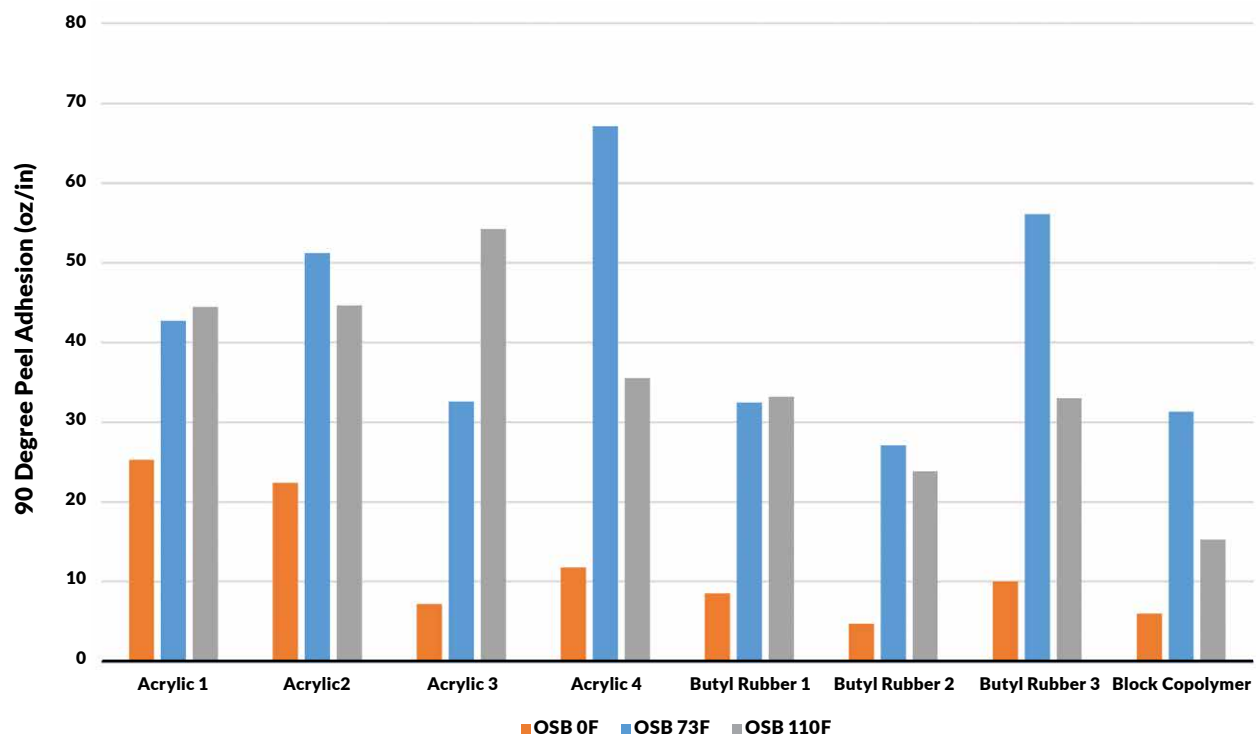
During these tests, a strip of tape is applied to a test panel with controlled pressure. The panel is placed horizontally into a test apparatus, and the tape is peeled from the substrate at a 90-degree angle at a constant speed while measuring the force. The measurements taken during this process illustrate the force required to peel the tape from the substrate. The threshold to pass the test is 24 oz/in, according to AAMA 711-20.

Peel testing was conducted on plywood and OSB at three temperatures: 0 F (-18 C), 73 F (23 C) and 110 F (43 C). Figures 4 and 5 provide the results for both substrates. The synthetic rubbers passed the test at room temperature. They reached an acceptable level at high temperature on OSB, for the most part, but some struggled on plywood. They all flatly failed during cold-temperature testing on both substrates.

**Figure 4. Peel performance comparison of acrylic adhesives vs. synthetic rubbers on plywood.**



**Figure 5. Peel performance comparison of acrylic adhesives vs. synthetic rubbers on OSB.**



The acrylic adhesives outperformed their synthetic rubber counterparts in room-temperature and high-temperature tests in most cases. Even at 0 F (-18 C), acrylic adhesives could maintain strong enough adhesion to reach the 24 oz/in passing threshold.

The most striking conclusion that can be drawn from these studies is the superior balance of properties offered by acrylic adhesives. As the figures illustrate, one synthetic rubber shows good peel strength at both room and high temperature, but it fails the peel test at low temperature and suffers from a complete lack of shear strength at high temperature. This would necessitate the purchase of multiple synthetic rubber-based flashing/seaming products in order to ensure acceptable results in varying climates.

In contrast, it is clearly evident that the performance of acrylic adhesives varies little in terms of both cohesive and adhesive strength at different temperatures and on multiple substrates—without the need for primer. The result is streamlined purchasing and installation processes, as just one acrylic-based tape is capable of providing long-lasting, high performance for a broad range of building envelope application environments.

## ACHIEVING THE PERFECT BALANCE

The slow, sliding movements that buildings experience due to temperature fluctuations and other changes may pose problems for some flashing/seaming products. Shear testing, which reflects an adhesive's cohesive strength and its ability to withstand these movements, is a critical measure in ensuring building envelope performance. As the testing has shown, the disparity between acrylics and other adhesive chemistries is apparent.

Acrylic adhesives offer higher shear strength than other adhesives on the market without sacrificing peel strength. They feature a broad operating temperature range and have the ability to effectively adhere to textured substrates without reacting negatively to other construction materials—all without requiring a primer in order to be effective. This balance of properties results in easy, no-mess installation while ensuring the flashing/seaming system's ability to maintain lasting strength and flexibility.

The use of acrylic adhesive-based flashing/seaming products provides wide-ranging, bottom-line benefits. Architects take pride in the long-term durability of their designs, while specifying engineers and contractors mitigate the potential for post-installation failure, liability risks and the need for costly rework. In addition, OEMs enjoy the broader customer base and deep brand loyalty that result from providing flashing/seaming products that ensure high-quality, long-term resiliency in the building envelope.

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**For more information about adhesives designed for building envelope applications, visit [shurtape.com/building-envelope](https://shurtape.com/building-envelope)**