

Self-Adhered Membrane Applications: What Does It Really Mean to Stick?

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INTRODUCTION

Self-adhered membranes come in a variety of colors, sizes, purposes, and designs. Whether it is for window and door flashing, roof underlayment, roofing membranes, air barriers, or below-grade waterproofing, the product's fundamental design is a membrane with a pressure-sensitive adhesive (PSA) designed to adhere the membrane to a surface. Depending on the target application, the self-adhered membrane can be comprised of a variety of materials and if the membrane is not self-adhering on its own can be coated with a separate PSA to provide the adhesion. When combined, these materials provide a functional membrane that will be adhered to a variety of construction materials, hence the name *self-adhered membranes*. With one of the fundamental performance criteria of the membrane being its ability to adhere, it begs the question: What does it really mean to stick?

PSAs are developed to balance the performance of adhesion, cohesion, and tack. The adhesion of a pressure sensitive compound is the ability of the material to interact with another material's surface. With a PSA, the interaction is not a curing process or a chemical reaction with the surface but rather an entanglement of the outer surfaces of the two materials, the strength of which is driven by the surface energies of the two materials. A high-surface-energy substrate will have a greater affinity for the adhesive and, as a result, a higher measured adhesion when measured by peel adhesion. **Figure 1** shows a typical orientation for a 90-degree peel adhesion test. Where adhesion is the affinity of the bonding substrate to the adhesive, cohesion is the affinity of the adhesive to bond to itself. This characteristic determines the inner strength of the adhesive layer and allows a PSA to maintain its integrity when external forces are applied.



Figure 1. Typical 90-degree peel adhesion.



Figure 2. Loop tack measurement.

Finally, the third main characteristic of any PSA, regardless of specific chemistry, is tack. This is the spontaneous ability of an adhesive to stick to a surface with no pressure applied or time to dwell on the surface. When handed a self-adhered membrane, the initial reaction by most people is to evaluate how sticky the material "feels"—this is often analogous to the amount of tack in the PSA. The evaluation of this property is performed in a lab scale using a variety of test methods. One such examples, as shown in **Fig. 2**, is loop tack testing which applies a loop of the material to the testing surface with no pressure and immediately removes the material measuring the near instantaneous force of the adhesive on the surface.

CURRENT TEST METHODS

The current evaluation techniques vary between the different types of self-adhered

membranes and the organizations that have developed the test methods; this paper will focus on commonly used ASTM test methods for evaluation of self-adhered membranes. These test methods are also often referenced in product specifications and acceptance criteria for self-adhered membranes in many applications. While it is common to use peel adhesion tests for product evaluations, it is important to note that not all peel adhesion methods are directly comparable or well understood. Separation rate, angle of peel, and sample preparation can all impact the expected comparability of the results.

ASTM D903, STANDARD TEST METHOD FOR PEELING OR STRIPPING STRENGTH OF ADHESIVE BONDS¹

This test method, originally published as ASTM D903-46T and most recently approved in 2017, is commonly used to evaluate the adhesion of materials to construction substrates. The benefits of this method are its simplicity and its ability to be used on a wide variety of rigid and flexible materials. The drawbacks for building enclosure applications are the limit of the test being only approximately 180 degrees (**Figure 3**), the sample preparation recommendation for a single panel, and the limits when using extensible materials.

For thick membranes (typically over 10 mils), the impact of orienting the membrane at 180 degrees creates an outsized influence on the recorded bond strength due to the need to continually fold the material back on itself during the test. While still technically

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Figure 3. Typical 180-degree peel adhesion.

allowable, the ability to evaluate the adhesive performance is diminished by the increased load from orienting the membrane as required by the method. The extent of this impact is impacted by the stiffness of the membrane and the overall membrane thickness. This method also includes the recommendation of preparing the bonded material prior to cutting the sample material to size. This preparation also allows for damage to the edges of the bond line and the underlying substrates, which can alter the measured strength of the bond. Last in this brief overview of the test method is the concern for extensible materials. When a material is able to elongate in the same force range as the peel test, the impact of peel strength and tensile strength of the elongating membrane are combined, and the rate of peel is altered by the extension of the membrane. The method correctly recommends reinforcement but gives no guidance on at what level the elongation of the membrane requires reinforcement and standardizes the criteria. This method also lacks a standardized approach to the sample preparation and pressurization of the material, leading to further variability.

ASTM D3330, STANDARD TEST METHOD FOR PEEL ADHESION OF PRESSURE-SENSITIVE TAPE²

Some of the concerns previously mentioned with ASTM D903 were addressed by the development of ASTM D3330. This test method includes six different methodologies for evaluating the bonding strength of a PSA to a surface of interest, including both 90- and 180-degree angles, as well as specific methodologies for evaluation of a material bonded to its own substrate. This method also includes a variety of precautions when utilizing it for anything other than single product evaluations. Specifically, in Section 5.3, the method states that the peel methods (other than liner adhesion) cannot be used to compare to different products due to the difference in backings and adhesive stiffness causing changes in the resultant measured

forces. Nonetheless, this method is referenced regularly to set the minimum standards for products, including AAMA, ICC ES, and ABAA material standards.

ASTM C794, STANDARD TEST METHOD FOR ADHESION-IN-PEEL OF ELASTOMERIC JOINT SEALANTS³

The inclusion of this test method in material standards for self-adhered membranes is a misapplication of a test method. This method is specifically written for the evaluation of joint sealants in peel. The entire methodology is based on the material being applied in an uncured state and embedding in the uncured material a reinforcement mesh to measure the peel value after a complete cure. The thickness of the joint sealant is defined by the test method, where for self-adhered membranes the thickness is determined at manufacturing not during the sample preparation. Without significant modifications to the test method for sample preparation, dwell time, application considerations, as well as the evaluation of separation (reinforcement failure, adhesion, cohesion, etc.) the method is not applicable as a self-adhered test method. With these modifications the test method then reflects other existing test methods (ASTM D903 and ASTM D330).

ASTM D1876, STANDARD TEST METHOD FOR PEEL RESISTANCE OF ADHESIVES (T-PEEL TEST)⁴

T-Peel testing, as shown in **Fig. 4**, is used to evaluate the adhesion of flexible materials in a T type configuration. This test method is another example of misapplication of a test method without properly clarifying the deviations



Figure 4. Example T-Peel configuration.

needed to use it as a method to evaluate the peel adhesion of self-adhered membranes. The method is designed to evaluate curable adhesive systems applied to flexible materials. In the introduction section of the test method care is taken to clarify the bonding condition, film thickness, layering of adhesive, cure times, etc., but these are material characteristics that are not relevant to pre-applied PSAs on a membrane. The method, if being utilized, must have a variety of modifications to consistently specify the sample preparation and testing parameters when utilized in the evaluation of self-adhered membranes.

ASTM D4541, STANDARD TEST METHOD FOR PULL-OFF STRENGTH OF COATINGS USING PORTABLE ADHESION TESTERS⁵

This test method was historically developed for the coatings industry and to use portable testing equipment. This testing is conducted by applying a test fixture to the surface to be evaluated, this fixture is typically glued to the exterior plane of the membrane, as shown in **Fig. 5**. The fixture is then attached to the portable adhesion tester which can apply force (perpendicular to the membrane surface) and a balancing counter force outside of the tested area. These adhesion testers can be mechanical, pneumatically, hydraulically, or electrically actuated. This method can also be adapted to be used for self-adhered membranes, but a few necessary considerations are required. First, this portable adhesion testing is more relevantly used in field applications rather than a laboratory environment due to the portability of the testing apparatus and the variability of the loading rate on the bonding line, specifically for the manually actuated adhesion testers. There are modifications that can be made to a constant-rate tensile tester that can allow for controlled rates of extension rather than relying on an operator for handheld or limited control for electrical, pneumatic, or hydraulic actuated testers. In a laboratory environment when testing materials

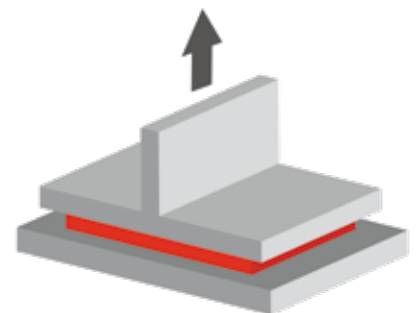


Figure 5. Asymmetrical loading of pressure-sensitive adhesive.

that are load rate dependent (self-adhered membranes) utilizing a constant rate extension tensile tester modified to run the test will ensure that the test is conducted at a repeatable speed. Additionally, the method was originally utilized for coatings that are uniform throughout their thickness, but when utilizing this method for materials that are composite in nature, care must be taken when evaluating the failure point of the sample, especially if the rupture occurs inside the composite membrane.

ASTM D7234, STANDARD TEST METHOD FOR PULLOFF ADHESION STRENGTH OF COATINGS ON CONCRETE USING PORTABLE PULLOFF ADHESION TESTERS⁶

Similar to ASTM D4541, this test method was developed to evaluate coatings, but specifically on concrete. This method is referenced in below-grade waterproofing material standards. For self-adhering membranes, many of the same concerns with this method persist as with ASTM D4541. Of note for this method was the work put into the appendix denoting the interpretation of failure modes of the bond (Appendix XI). Specifically, in the section on elastomeric coatings, which discusses the impact of edge peeling on the results for low-modulus elastomers. Most PSAs have similar performance at low loading rates which can impact the interpretation of the results.

NON-ADHESION TESTING

There are also a few test methods that evaluate the functional performance of an adhesive without specifically testing the adhesion of the material to the substrate. These test methods are also included alongside adhesion testing in material standards for a product, but rather than trying to directly evaluate the adhesion of the material these tests evaluate the functional performance of the self-adhered membrane in application. Two such examples are ASTM D7281⁷ for roofing membranes and ASTM D5385⁸ Modified for below-grade waterproofing. ASTM D7281 evaluates the performance of a seam of a roofing membrane (not necessarily a self-adhered membrane, but possibly) under ponding conditions and differential pressure. For a self-adhered membrane, this allows a functional evaluation of the ability for external and internal pressures to be withstood while maintaining a watertight bond. ASTM D5385 Modified allows the evaluation of a waterproofing membrane that has an intended leak point in a controlled location, the material is then evaluated for its ability to prevent the

lateral passage of water between the membrane and the concrete. This test as well is not directly measuring adhesion but rather the ability of the adhesive solution to meet the core requirements of the application.

TESTING METHODS SUMMARY

The majority of test methods utilized for the evaluation of a PSA are peel forces applied at one or two orientations. This is evidenced by the results listed in unit force per unit width. This means that the evaluation is not of the performance of the material as a whole but rather the ability of the adhesive to resist loads directly at the bond line, which does not take into account the benefit or impact of the facer material, the ability of the membrane to spread loads, or other forces that are commonplace in application (such as shear, cleaving, or dynamic loading) and may bias results towards thicker products simply due to the force required to assemble a test sample in the required orientation.

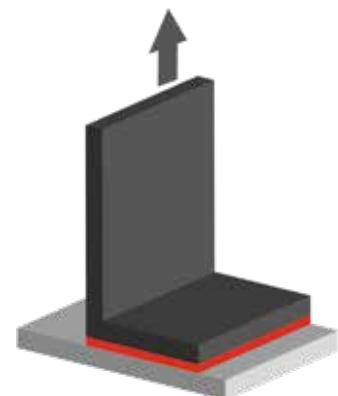
SELF-ADHERED MEMBRANES IN APPLICATION

As previously discussed, self-adhered membranes may be and are utilized in a variety of building enclosure applications. As each application will have different contributing factors impacting the performance of a self-adhered membrane. Each application will have its own unique characteristics but there are many common characteristics that impact the performance of a self-adhered membrane. The characteristics discussed in the following sections are applicable to all building envelope applications and the evaluation and selection of self-adhered membranes.

FIELD OF SELF-ADHERED MEMBRANES

When utilizing a self-adhered membrane applied to a rigid structural material (roof deck, sheathing, foundation, etc.) as the substrate, when installed only the edges of the membrane can initiate a peel. As represented in the peel adhesion test methods, the material to fail in peel must have a portion or edge that is able to apply pressure (at a variety of angles) that will allow a liner peel force to be initiated. Since peel forces are not relevant at this location in the design, other forces must be evaluated. The first forces to consider are the shear forces on the membrane. These are any forces that result in a loading parallel to the bonded area. In the review of the current common test methods, none of them measure this characteristic directly. In vertical applications, this is initially from the weight of the material itself. Additionally, the material may experience shear

loads from other materials that are bonded to the material, where the adhesive is the load-bearing pathway for the secondary material. There also could be shear loads from friction forces on the surface of the membrane; these can be caused by air moving past the membrane or other parallel loads applied to the surface of the membrane. These loads in the final design can be decreased by any fixturing that penetrates the membrane (brick ties, Z-girts, clips, etc.), which would support any shear loads. In horizontal applications, there is an additional shear load from pedestrians in areas where people may walk on the membrane. In addition to the shear loads mentioned in the field of membrane, there are also perpendicular loads (often referred to as pull-off, tensile, uplift, etc.). The benefit of self-adhered membranes is that when they are exposed to these loads, they can dissipate the load over a large, bonded area rather than point loading in a mechanically attached system. These forces are most often driven by pressure differentials between interior and exterior conditions. When there is internal positive pressure and a pathway to the membrane (a hole, crack, gap, etc.), there will be a force exerted on the self-adhered membrane. The load is dependent on the pressure differential across the membrane and the impacted area of the membrane. An important distinction is that the force on the membrane is isolated to the area that is exposed to the pressure differential; in areas where the membrane is bonded to the rigid substrate, the rigid substrate will withstand the load from the pressure differential. The force is then dissipated to the surrounding adhesive by the membrane. This force, as applied, is not a peel, shear, or strict tensile load. This can be described as an asymmetrical tensile load or a cleaving load as shown in **Fig. 6**. This type of load will be a combination of peel, tensile, and shear loads at the same time. If there is a failure of the adhesive, the material will continue to balloon, resulting in a bubble behind the membrane. After



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Figure 6. Asymmetrical loading of pressure-sensitive adhesive.

the pressure load is removed, the membrane may then readhere, but the repeated loading may lead to degradation of the PSA.

EDGES AND TRANSITIONS

As with most other building envelope products, the transitions, terminations, and seams are the most critical areas for issues. Although peel is possible at the edges and transition points, the ways the materials are tested are also unlikely to be achieved (90- or 180-degree peel angle). Although the seams of the material are unlikely to peel at the tested angles, they are a critical interface for evaluation. One area of specific concern is a pressure differential at the lap seam. As discussed in the previous section, when a pressure differential is applied to a membrane that is not adhered to a rigid substrate, the membrane must then dissipate the load; this is even more critical when the load is applied at a seam or a transition. In addition to the previous loads at a seam, there is also a shear load on the two membranes at the seam, requiring sufficient shear strength in the adhesive to prevent the seam from bursting. This is applicable at all seams within a single material as well as transitions between different types of materials.

TEMPERATURE IMPACTS

The current test methods consider limited temperature exposure for adhesion. By default, these tests are conducted at room temperature (23°C 50% R.H.) but in practice these membranes will be exposed to a wide variety of temperature profiles. PSA tapes are temperature-dependent viscoelastic materials, which means that their ability to withstand loads is dependent on the temperature at which the load is applied. When exposed to elevated temperatures these adhesives will soften and lower their resistance to the variety of forces to which they are exposed. Conversely when the adhesives are exposed to lower temperatures, they tend to become more rigid and can withstand higher forces than measured at room temperature. While more rigid the adhesives can also become more brittle so dynamic impact loads may cause a rupture in the bond. There is also a distinct difference between the temperature to which the adhesive is exposed and the temperature at which the membrane is applied. The same softening and hardening of the adhesive can occur prior to application but when applying the membrane, the softer adhesive will bond faster and result in an overall greater bond and the rigid cold adhesive may not bond at all depending on the temperature of application. Care must be taken that the loads described in the previous sections can and will

be accommodated over the expected range of exposures and the impact of the temperature on each of these forces will be product dependent.

LOADING RATE

Another important characteristic to consider is the ability of PSAs to withstand extended loading times. The adhesives' resistance to all of the loads mentioned is rate dependent, meaning that the rate at which the load is applied has a direct impact on the overall strength of the bond. Most often for PSAs, when a load is applied slowly, the overall strength measured is lower, and when the load is applied rapidly, the overall strength is greater. Also, the way the material fails can depend on the speed of application of the load as well with rapid application making the adhesive more rigid. The ratio between these loading speeds is not necessarily linear and consistent between different types of adhesives, so it is important to ensure that the rate of the bond is known (that is, long, slow load application versus rapid, dynamic loading), and the impact it may have on how an adhesive behaves must be considered.

LOADING DURATION

In addition to the load rate of the adhesive bond, it is also critically important to understand load duration. Static loads applied over a long period of time can result in creep of the bond line and failure at a much lower load than dynamic short term loading. This is critical for membranes where it is expected that there will be constant static loads on the bond that the evaluation take into consideration the requirement to resist loads applied over a long duration rather than short term tests.

CONCLUSIONS

The evaluation of adhesives for use in self-adhered membranes is a multifaceted approach. The current techniques for evaluating bonds are limited to peel adhesion in various forms that are not often directly comparable. In practice, most adhesive bonds from self-adhered membranes are exposed to loads that require resistance in shear or tensile (pull-off) versus peel, and the testing techniques for self-adhered membranes are limited in their evaluation of these characteristics. In addition to the types of loads, it is important to consider and evaluate how these bonds will be able to withstand the applied loads over a wide variety of exposure conditions, as the adhesives used in these materials are dependent on the temperature at which the load is applied. Finally, the loading rates and expected loading times are necessary when holistically evaluating the bonding performance of a PSA. 

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Cody Shelner is an experienced expert in the pressure-sensitive adhesive and self-adhered membrane industry. With a background in mechanical engineering, he has contributed significantly to the

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