

Pressure-Sensitive Adhesives in Roofing

Paul A Benensky
Senior Research Engineer
CertainTeed Corp.
Blue Bell, PA

The first known patents for a self-adhered low-slope roofing product is from Tajima in 1975, describing an asphalt formula and process for making bitumen-based self-adhered roofing membrane laminate. These early patents described asphalt modified with synthetic rubber and resins. In the early 1980s, this technology was used to develop a self-adhered steep-slope roll underlayment designed to protect homes from ice dams formed at the roof edge or eaves. Further SA tapes were developed for flashing details (at walls, parapets, roof penetrations, etc.) and as a seam sealing tape for EPDM roofing materials.

This paper will give a brief history and list self-adhered tapes that are used in the roofing industry. Then the main focus will then be on modified bitumen (asphalt) self-adhered roofing materials used mainly as ice and water dam protection and as low-slope roofing membranes. Focus will be on polymer selection, additives and their effects. Roofing industry test methods will be presented to help describe what characteristics make a functional self-adhering roofing material.

Butyl rubber tapes were being used to seal low-slope (less than 4 inches rise in 12 inch run) since before 1980. In a paper presented by Haddock and Dutton¹ at the 2011 ASTM D08 Roofing Research and Standard Development symposium, a 40-year-old roof was reviewed where pressure sensitive butyl rubber tape was used to seal the metal panel seams. A sample was removed from the roof and, after a thin layer of outer oxidized surface was removed, testing showed that the butyl rubber tape still met the manufacturer's specifications.

Butyl rubber, often in combination with EPDM polymer, is also used as seam sealing tapes in EPDM (ethylene propylene diene monomer) single ply low-slope roofing membranes, as a flashing material, and on high end ice and water dam protection. Butyl rubber is used principally for its ability to flow and wet out the surfaces to be sealed, and then to be hydrophobic and resistant to age degradation.

Even with all of those butyl rubber tape uses, industry numbers show that there is over twice the area of modified asphalt based self-adhered roofing membranes applied and over ten times the area of modified asphalt based roofing underlayments applied in the US market annually.

Of course, the overall driver is price. Butyl works, but you can get the same function from a polymer modified asphalt composition, including pressure-sensitive characteristics, ability to flow, substrate wet out and hydrophobicity. Neither the standard base polymers used nor the asphalt alone does it well, but in combination modified asphalt self adhering compounds are a very effective adhesive, sealant and water proofing membrane.

Asphalt by itself is an interesting substance. In “The Shell Bitumen Handbook”, asphalts or bitumens ”are separated into four groups; asphaltenes, resins, aromatics and saturates.”² I will not try to describe each of these constituents, but simply say that asphalt is “soup”. But it is soup with some interesting characteristics. Asphalt qualities include “...cohesion; adhesion; durability...”³ much the same as pressure-sensitive adhesives. Cohesion being internal strength, adhesion being attraction to other materials and durability is “...the ability to maintain satisfactory rheology, cohesion and adhesion...”⁴.

Asphalt can be oxidized to a softening point of over 200°F, but becomes much too hard and stiff to be of use as a pressure-sensitive material. Most asphalt used for ice/water dam protection and for self-adhesive membrane roofing are soft, with high adhesion and moderate to low cohesion and durability.

We use ASTM test methods D-5, Test Method for Penetration of Bituminous Materials and D-36, Softening Point of Bitumen (Ring-and-Ball Apparatus) for measuring the cohesion and durability of asphalt, along with other proprietary tests.

ASTM D-5 uses a specific needle with weight that is allowed to penetrate the surface of the asphalt for a set time at a set temperature, a standard is 100 grams weight, 25°C for 5 seconds (see figure 1). The measurement is taken in deci-millimeters (dmm). Alternate temperature ranges, weights and durations are often also tested in conjunction with the 25°C for better characterization, but we will focus on 25°C for this paper.



Figure 1, Penetrometer

ASTM D-36 Ring-and-Ball method measures the temperature at which the asphalt material will start to flow under a specified force, modified to use the Mettler FP 83 Dropping point apparatus (see figure 2). The sample is poured molten into a small shouldered ring and allowed to cool. When cool, a metal ball with weight of greater than 3 grams is placed on the asphalt surface. The Ring is such that the ball will fit tight inside the ring and be caught by the shoulder at the bottom. The sample is placed in the FP 83 and the temperature is increased at 3.6°F (2°C) per minute until the ball forces the now re-molten asphalt out the bottom of the ring where it interrupts a light beam. The temperature at which the asphalt breaks the light beam is then determined as the softening point.



Figure 2, Softening Point Tester

Asphalts used for self-adhering roofing modification have a softening point usually between 100°F and 150°F, and a 77°F penetration of greater than 100 dmm. Asphalt that has a softening point of only 100°F to 150°F would become molten at normal roof temperatures. For obvious reasons, this is not recommended for use by itself. Also, a penetration of over 100 dmm demonstrates poor cohesive strength and poor durability due to ability to flow at expected roof temperatures of greater than 150°F (poor rheology). This asphalt is great for adhesion and sealing, but not very good for staying where you stick it.

This is where polymer modification helps. In the late 1960s and early 1970s, Europe pioneered the use of polymer modification of asphalt, specifically to make low-slope roll roofing. One of the prime polymers used was SBS, Styrene-butadiene-Styrene tri-block. They found that when mixed into hot liquid asphalt (greater than 300°F) under shear the polymer would dissolve. Then, as the asphalt and polymer cooled, they would phase separate. The polymer becomes the backbone forming essentially a foam matrix, and the asphalt fills the voids and acts as the water proofing agent. Softening point is now above 250°F and 77°F penetrations are below 50 dmm. Immediately after cooling to room temperature, this matrix can be seen under UV light and magnification. The asphalt is transparent and the polymer reflects the UV light (see figure 3).

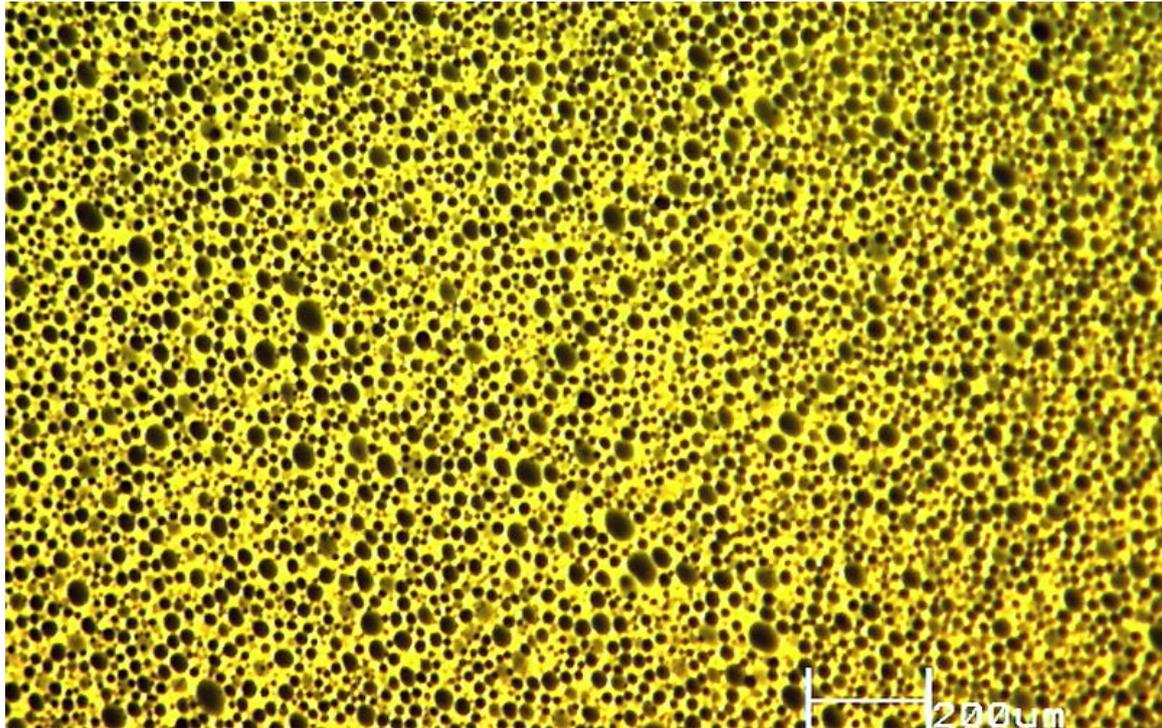


Figure 3, SBS matrix in Asphalt

The material is usually manufactured using a process by which a nonwoven mat of polyester or fiberglass is coated and/or submerged in a pan of the modified asphalt at temperatures above 300°F so that both sides of the carrier mat are coated. The coated carrier is then pulled between two gapped steel rolls that meter the thickness, top and bottom, of the coated material and also ensure full impregnation of the carrier mat. The impregnated and coated carrier mat exits the coater and surfacing agents are applied top and bottom. The material is then cooled and wound into rolls. Self adhesive materials are manufactured in much the same way with the bottom side surface agent being a release liner.

To apply this modified asphalt roll to a roof, hot liquid asphalt is spread out on the roof deck and the polymer modified roll material is laid on top while the asphalt is still a hot liquid. The asphalt then bonds to the roll's asphalt/SBS matrix as it cools. This can then be built up usually in two or three plies to complete the roof membrane.

The first known patents for a self-adhered modified low slope roofing product were by Tajima in the 1970s⁵, describing an asphalt formula and process for making bitumen based self-adhered roofing membrane laminate. These early patents described asphalt modified with synthetic rubber and resins. In the early 1980s, this technology was used to develop a self adhered steep slope roll underlayment designed to protect homes from ice dams formed at the roof edge or eaves. By the early 2000s, self adhered low-slope modified asphalt roof membranes were commercially available.

Compounding a pressure-sensitive modified asphalt roof formulation is based on the initial European work. Standard Tri-block SBS polymers have excellent cohesion, but poor adhesion. Introduction of SB di-block into the SBS tri-block or using SIS

polymers sacrifices some of the cohesive strength, but greatly increases adhesive strength. As described by Tajima, use of resins or oils can then work with the polymers and further increase adhesion and pressure-sensitive performance.

The following table demonstrates the affect on the physical properties of penetration and softening point along with 180° Peel adhesion to plywood (as measured by test method referenced in ASTM D1970⁶). The peel samples were prepared by draw down, depositing 20 to 40 mils of molten modified bitumen onto 170 g/m² polyester nonwoven mat. After cooling, a release film was used to protect the adhesive surface. Softening point is a representation of cohesion, penetration relates to durability and the 180° peel is the measure of adhesion.

Table 1, modified asphalt compounding

		A	B	C	D
Asphalt		67.5	67.5	63.75	63.75
Star SBS		7.5			
>50% di-block SBS			7.5	7.5	7.5
Oil				3.75	
Tackifier					3.75
Calcium Carbonate		25	25	25	25
Filled blend test results	Value				
77°F Penetration	dmm	40	60	75	60
Softening Point	°F	260	205	195	200
Adhesion to Plywood	lb/ft	20	40	60	70

Compound A is a representation of a common SBS modified asphalt used for roll roofing as described above. The adhesion is in pounds per linear foot. Though the material has some finger tack due to the soft asphalt, overall adhesion is poor. Cohesion and durability are good, with a softening point well above normal roof temperatures and a penetration below 50 dmm. To get this material to bond to any ply above or below, some type of adhesive is necessary.

Compound B demonstrates the affect of introducing di-block into the polymer. Durability slips a bit with an increase in penetration, cohesion also is reduced with lower softening point, but adhesion increases 50%. Two notes from experience are that, even at twice the adhesion, the number is on the low side, and also adhesion at lower temperature becomes suspect. At about 35°F most asphalt stiffens to the point that they lose adhesive properties. Without some way of activating the polymer, lower temperature adhesion would be suspect.

Compound C is a good compound for an ice and water dam protection modified bitumen. The oil is chosen so that it swells the styrene areas of the SBS di-block, adding adhesion, as demonstrated by the increase in 180°F peel adhesion to 60 lb/foot. Notice that the cohesion is down, and durability is also down considerably, with the high penetration number. The softening point of 195°F is not uncommon for ice and water dam materials, and is acceptable as the overall mass below the mat is usually less than 15 mils. Also, multiple fasteners penetrate the mat and hold it in

place, therefore that rheology durability is not an issue after application. In fact, this lower durability and less resistance to flow is an asset for ice/water dam protection. These products are coated the same as standard modified bitumen with a release liner attached to the bottom side.

Ice and water dam protection is designed to protect homes from winter ice dams formed at the roof edge or eaves. This is a northern climate phenomenon where there is exposed roof deck that is not under the house proper as the roof extends out and includes an eave, or overhang with the bottom eave areas exposed to the elements. After a snow fall or ice event, the roof area above the eave has snow or ice frozen directly to the roofing shingles. Further up the roof surface, the roof deck area is over the living space. Heat rising from the living space can radiate through the roof deck and underlayment, melting the ice and/or snow in direct contact with the shingles. This melt then travels down slope where it is blocked by the frozen ice and/or snow over the exposed eaves. The water backs up under the shingles and then can leak through the roof deck along the nails or fasteners and into the house down the inside face of an exterior wall.

Other areas where ice and water dam protection is effective are in valley areas and around dormers. These transition areas make up for difficulties in applying a water-shedding layer of shingles. Ice and water dam products often have a sand or granule upper surface, although higher end products may have film top surfaces (see figure 4 below).



Figure 4, ice and water dam protection

With a high di-block content, a softening agent and soft asphalt, this formula adequately seals to the plywood roof deck so that water cannot migrate between the roofing material and the plywood deck. The low durability also allows the modified asphalt compound to seal around the penetrating nails that hold the shingles in place. ASTM D-1970 includes a section labeled “Self Sealability (Head of Water Test)” specifically designed to ensure that this property is present. The test design includes covering a piece of plywood with your ice and water dam protection, driving a nail through the center of the material and backing the head out ¼ inch, exposing the nail shank. Sealing a 1 gallon can around this nail (the can has the bottom removed and a suitable caulk is used to seal the bottom edge of the can to the product) and then filling the can to 5 inch depth with water. The head of water is left for 3 days and then emptied. The point of the nail extending through the deck is examined for water drips and the plywood around the nail penetration below the product is examined for water infiltration. Any sign of water is a failure. This is a rather extreme test but a very good representation of performance on a roof in an ice dam event. Overlap areas or Lap Integrity is also tested in ASTM D1970 as the material must be able to seal for itself. Below is an excerpt from ASTM D1970 for Lap Integrity.

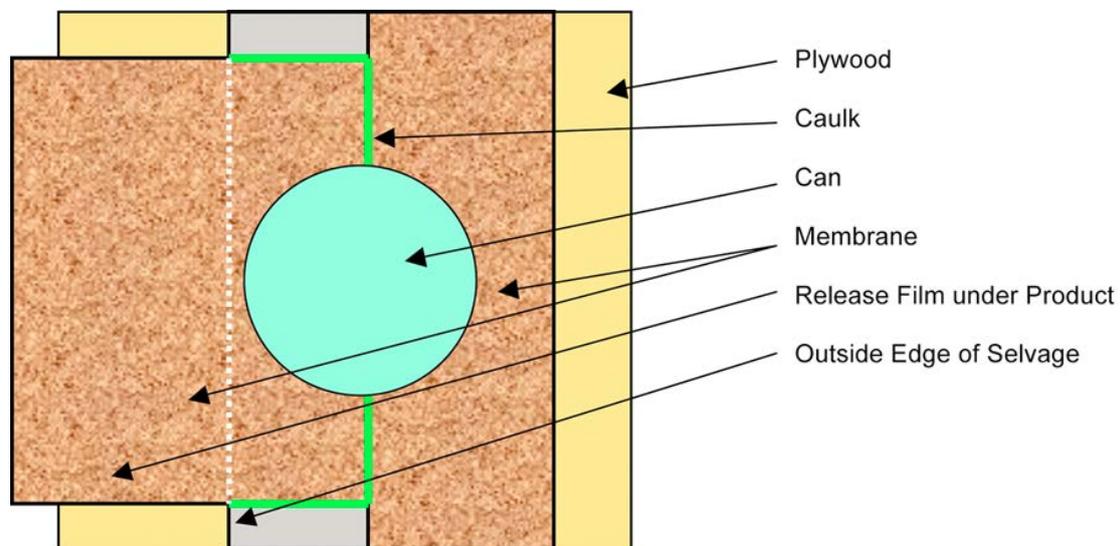


Figure 5, ASTM D1970, Lap Integrity

Formulation D is an example of mis with use as a possible low-slope modified roofing material. This type of product made a commercial impact in the mid 2000s. A tackifier is used to ensure bonding to multiple surfaces and also to retain durability and cohesion. Choice of tackifier and polymer can significantly improve all characteristics, and this is very important as the pressure-sensitive coating is your only mode of roof membrane adhesion and water proofing seal. These commercial products are then tested to industry standards such as FM Global’s wind uplift testing. CertainTeed has developed systems that have wind uplift resistance (which relates to resistance to uplift or separation of a roofing membrane from the roof deck during high wind events) that pass at a rated 105 psf negative pressure, which is double the Miami/Dade County Florida minimum wind resistance. The top side or cap commercial self adhered roofing rolls often have a granule covering, and the lower plies are covered with a film that promotes adhesion to the pressure sensitive product that will be applied in the above layer or ply. The coating method may be the same as

standard modified bitumen or may include two coating heads, one for the upper surface and one for the pressure sensitive side. Figure 5 shows a granulated cap sheet being applied over a film surfaced ply sheet.



Figure 6, granulated self adhered cap sheet over film topped ply sheet

A third use of pressure sensitive roofing is as a secondary full water-resistant covering under metal and tile roofs. These materials have upper surfaces specifically designed to either protect the under side (metal roofs) or act as an anchoring surface (tile roofs). Metal roof underlayments have an upper surface that is non-abrasive to the metal panels. The metal panels move considerably with respect to the roof deck during heating and cooling. A granule or sand surface would scratch through the protective coating on the metal and oxidation could occur, greatly reducing a metal roof's life. Film topped products are used for this application, often with a rough surface to promote safety when walking during metal roof application. Figure 7 is an example of this type of an underlayment under a metal standing seam roof.

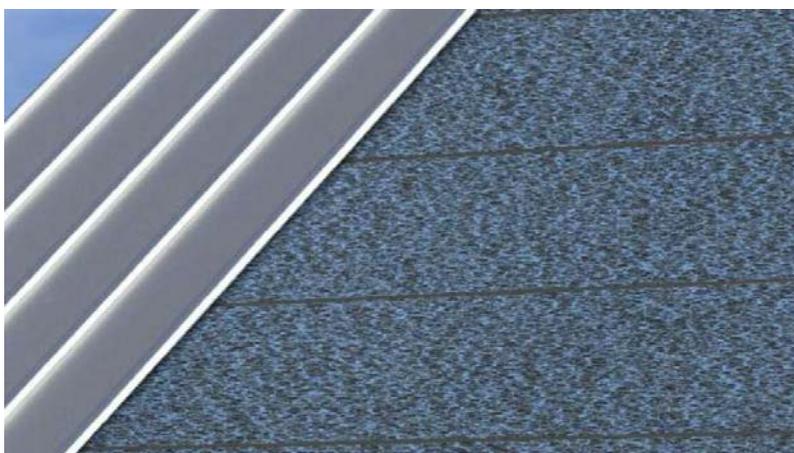


Figure 7, metal roof self adhered underlayment

Clay or cement tile roof underlayments need an anchoring surface as lower slope roofs often use a foam adhesive as the primary anchoring of the tile or with mechanical fasteners for additional tile securement. A pressure-sensitive product topped with a granule or nonwoven substrate is used as the spray in place foam adhesives bond well to these surfaces. Self-sealing is still necessary as fasteners may be used. An example of a nonwoven mat surfaced tile underlayment can be found in figure 8.

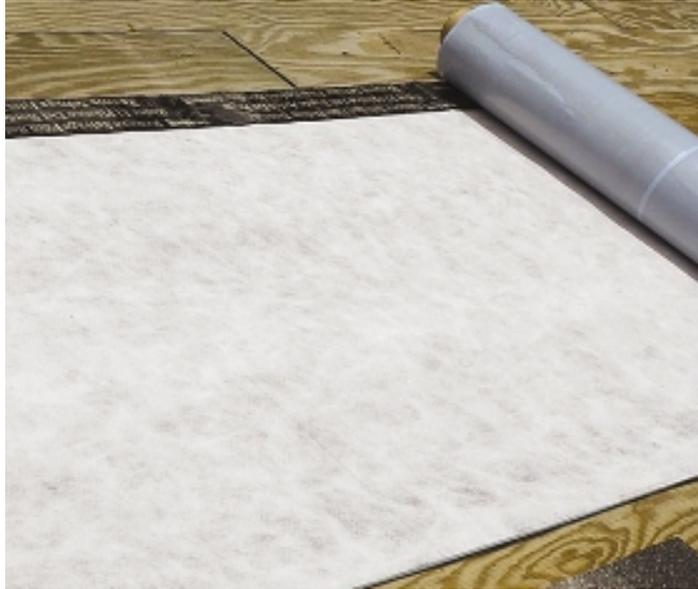


Figure 8, nonwoven mat topped tile underlayment

This is by no means a complete representation of all pressure-sensitive products used in roofing. The focus has been on modified asphalt, which has the highest use. When considering a pressure-sensitive roofing product, three things are paramount, the compound must be waterproof, self-sealing and durable enough to last for years under the weathering part of a roof system or as the primary waterproof covering. Using polymer modification of asphalt creates a waterproof and adhesive system that is used both in commercial and residential roof systems. The use of asphalt as the primary waterproofing agent and polymers as the backbone creates affordable pressure sensitive roofing systems.

¹Service Life Assessment of a Low-Slope 55 % Al-Zn Alloy-Coated Steel Standing Seam Roof System; Roofing Research and Standards Development, 7th volume
Haddock R., Dutton R.

² “The Shell Bitumen Handbook”, Shell Bitumen, UK, Riversdell House, Surrey,
England, 1990 – Page 90

³IBID – 36

⁴IBID – 40

⁵US3,937,640, US4,039,706, US4,091,135, US4,091,135

⁷ D1970-09 Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection,
2011 Annual Book of ASTM Standards, Section Four, Construction, Volume 04.04