

Performance Properties of Interply Adhesive Used with SBS-Modified Bitumen Membranes

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Key Words

Modified bitumen, SBS, cold adhesive, self-adhesive, torching, interply adhesives, mopping asphalt, cyclic joint displacement and peel tests.

Abstract

There are more options than ever for adhering modified bitumen sheet materials, including hot asphalt, heat welding or torching, liquid cold adhesive and self-adhesive. When SBS- (styrene-butadiene-styrene) modified bitumens were introduced in the United States in the late 1970s, the majority of the U.S. contractor base was built-up roofing (BUR) oriented. Familiarity with hot asphalt application and practicality of dealing with existing equipment made installation of SBS-modified bitumen membranes in hot asphalt an easy choice. However, in the years since, laboratory testing and field experience have demonstrated that other interply bonding choices – solvent-based adhesives, heat welding and heat-activated self-adhesives – offer higher performance. Some fundamental characteristics and performance differences of various types of interply attachment methods specific to SBS-modified bitumen roofing membranes will be emphasized in the paper as well as practical considerations for choosing the appropriate application method

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Introduction

In recent years, there has been a trend (pioneered by a small number of membrane manufacturers) to shift the application of modified bitumen roof membranes from hot asphalt toward better interply adhesives. As the modified bitumen roofing market in the United States continues to evolve and the benefits of cold adhesive and heat welding are more commonly understood, these methods are being used more frequently. They provide an alternative means of attaching modified bitumen materials that is particularly attractive when compared with hot asphalt.

Self-adhesive modified bitumen membranes occupy a small but growing presence in the marketplace, and the jury is still out as to whether they will be able to reach the mainstream. More important are the questions regarding their long-term performance in low-slope roofing applications.

Properly applied cold adhesive and heat-welded modified bitumen membrane systems achieve a tenacious interply bond strength that surpasses that achieved with oxidized asphalt applications. Further, cold adhesive and heat-welded membrane systems exhibit superior physical and mechanical properties and rooftop performance in both the long and short term as compared with oxidized asphalt applied membranes.

BACKGROUND

All Mopping Asphalt Are Not The Same

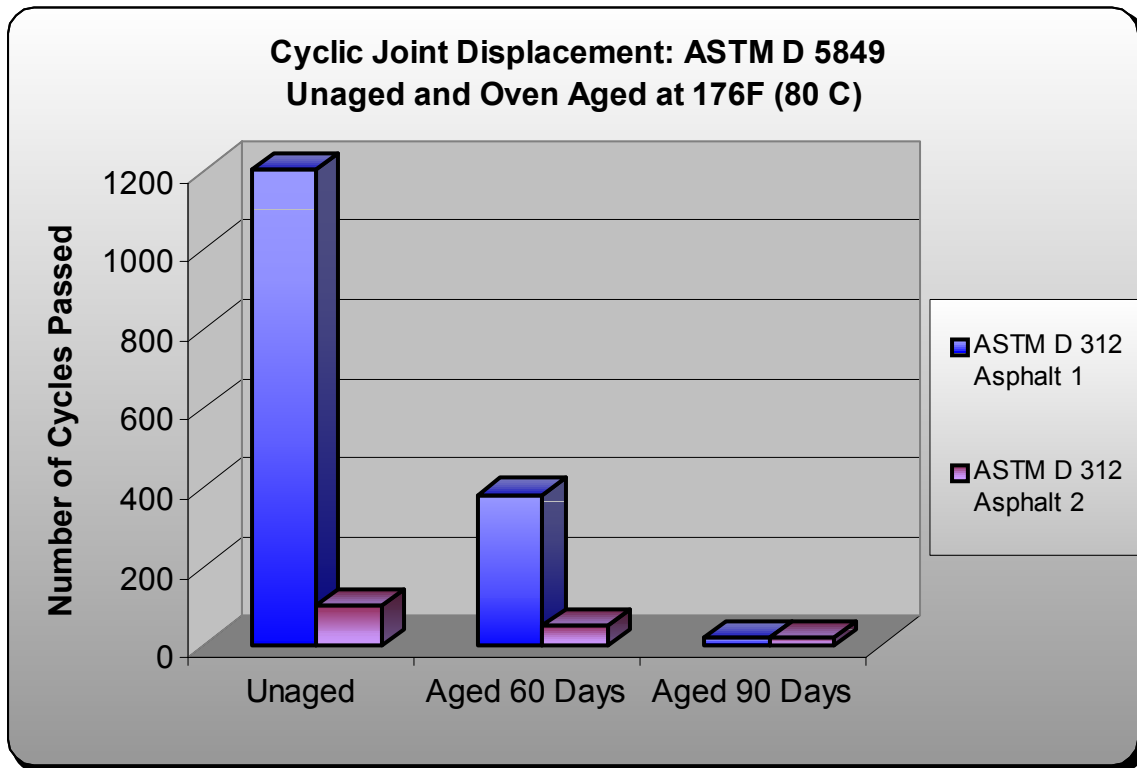
Just as all modified bitumen sheet goods are not the same quality, neither are all ASTM D 312, Type III or IV asphalts. Although oxidized asphalt as an interply component in the overall membrane assembly is seldom given a second thought, it must be noted that differences in ASTM D 312 mopping asphalts exist that can affect the long-term performance of the modified bitumen membrane assembly. Not all ASTM D 312 asphalts yield good long-term results even when used in conjunction with the highest quality SBS-modified bitumen membranes. This was briefly discussed in a Construction

Technology Update published by the National Research Council of Canada (NRC) in 2000.¹ Currently, there are more than 50 asphalt plants in the United States. At each of these oxidizing plants, the asphalt flux sources can change often. This leaves the consumer slim odds that a key ingredient in a modified bitumen roof membrane assembly will remain consistent from job to job or even day to day. Monitoring the quality of mopping asphalt is not an easy task because of the factors previously mentioned: number of asphalt plants, variability in asphalt fluxes used in these plants, and the sheer logistics of sampling and testing. The only true way to ensure total system compatibility is to purchase mopping asphalt from the same plant that supplies the asphalt used to produce the modified bitumen sheets. This is seldom offered as an option.

When used to adhere the same SBS-modified bitumen sheets, different mopping asphalts perform quite differently over time. If all application technique related variables are dismissed, one critical element remains: the quality of the interply bonding agent. Bond strength plays a major role in the long-term performance of any membrane assembly.

All oxidized mopping asphalts embrittle over time. It is the nature of the beast. Cyclic joint displacement (cyclic fatigue) results give a good indication of this phenomenon. This test procedure can differentiate between two mopping asphalt sources where other tests, including peel testing, may not. As pointed out in Figure 1, when mopping asphalt ages, it loses its bond strength and ability to resist blister growth when voids exist in the interply. For this reason, even the best mopping asphalt will eventually be the weak link in a hot asphalt applied modified bitumen system. Although the two-ply SBS membrane represented in Figure 1 did not rupture, the asphalt disbonded in the interply. Asphalt 1 maintained adequate bond strength for more than 20 years of equivalent heat aging. Asphalt 2, on the other hand, performed poorly from the day of application. This laboratory data has been substantiated by field experience. Although years of experience and laboratory data had proven this ASTM D 312 Asphalt 1 to be "best of class," it was acknowledged that better interply adhesives were available that would either eliminate or mitigate the weaknesses found in all hot asphalt applications.

FIGURE 1



Torching or Heat Welding

Modified bitumen roof membranes have been torched in Europe for more than 30 years and in North America for more than 25 years. Certain SBS sheet goods are specifically designed for torching and are available with patented surface treatments intended to enhance torch welding and make the products more efficient to install.

Torching, however, is becoming less of an option because of the perceived fire risks. Local building codes sometimes ban torching, and some companies go so far as to invoke no-torching policies on their buildings. The most challenging hurdle for the future of torch application is the rising cost of insurance for the roofing contractor. Even in Canada where torching of SBS-modified bitumen has been the norm for 20 years, the rising cost of insurance is forcing contractors to take a strong look at alternative application methods.

Theoretically, it is impossible to improve upon the interply bond strength of properly torched membranes. When torched correctly, the rubberized (SBS) or plasticized (APP) asphalt compound on adjoining sheets becomes one homogeneous layer of modified bitumen. This in essence yields the ultimate composite condition for a modified bitumen membrane: an interply weld comprised of fused modified bitumen compound from both

sheets. As with any application technique, mistakes can be made when torching or heat welding. Underheating will not adequately fuse the sheets together, making interply blisters possible. Severe overheating certainly leads to poor aesthetics and potentially long-term performance problems. Keep in mind that SBS and APP are quite different polymer systems, and they do not torch the same.

Self-Adhesive Membranes

Another application option exists that at a glance seems to reconcile all the road blocks associated with mopping, torching, and liquid cold adhesives. This system consists of modified bitumen membranes coated with a “self-adhesive” bitumen formulation. These self-adhesive or peel-and-stick systems are indeed growing in the low-slope marketplace, and they do have their place. These products are also enjoying a burgeoning market for use as underlayment for steep-slope roofing. This paper addresses their use in low-slope applications. Unlike all the other methods for adhering modified bitumen, self-adhesives dispense with the need for any form of liquid adhesive. Therefore, there are no fumes, VOCs, or flames on the rooftop. This is the benefit of self-adhesives. It also happens to be the drawback. Because there is no form of liquid to wet and fully penetrate the surface of the substrate, more care must be taken during installation.

Probably the single biggest challenge for these products is the drastic change in modulus and adhesive properties of the self-adhesive bitumen compound with changes in temperature. Most manufacturers of self-adhesive modified bitumen list 10°C (50°F) as the low temperature limit for application. A few publish slightly lower application temperature limits. At temperatures below 10°C (50°F), the modulus of the self-adhesive bitumen is quite high and tack properties suffer accordingly. Self-adhesive materials should be kept warm just prior to application in cool weather. Hot-air equipment may be used to warm the self-adhesive surface prior to installation.

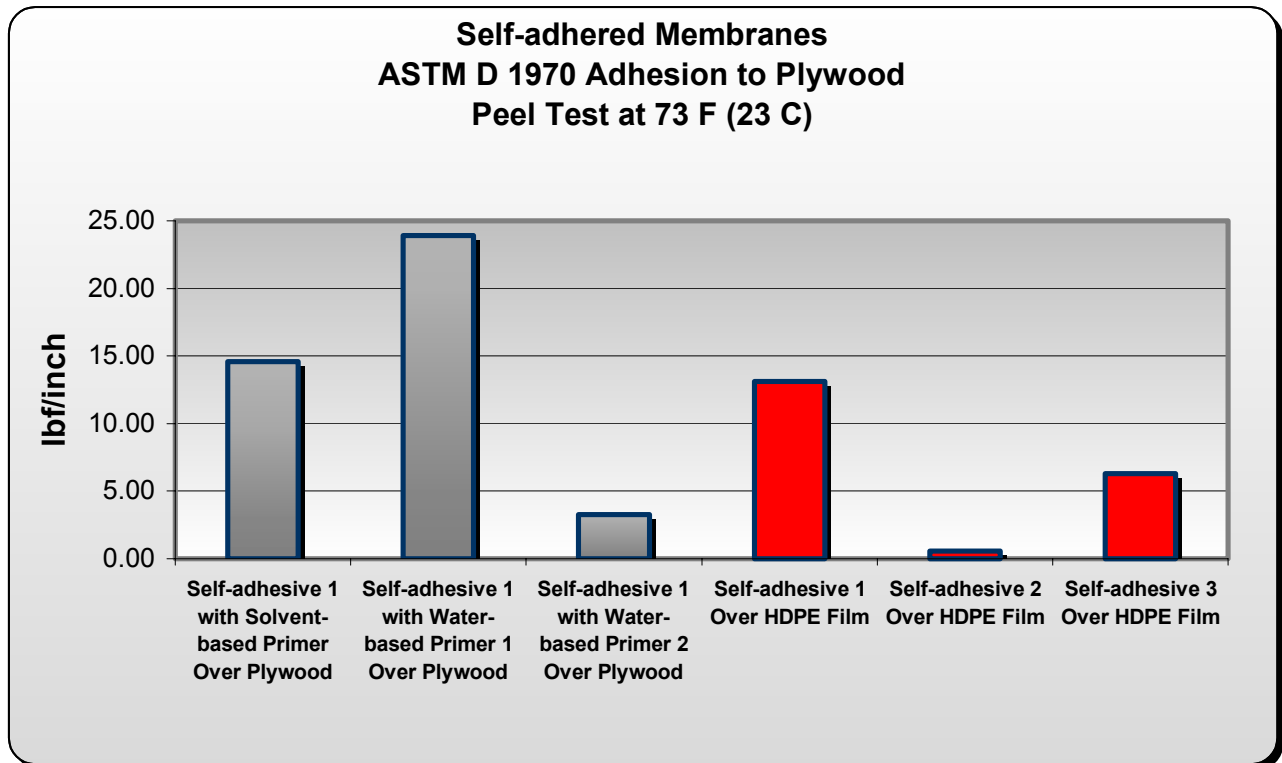
Compared with conventional application techniques, proper adhesion for self-adhesive products is more dependent on the surface roughness of the substrate because there is no liquid to fill irregularities. In this case, the self-adhesive membrane will bridge any gaps in the substrate surface. Primers should be used in virtually all cases. Even when surfaces receiving the self-adhesive mod bit are smooth and regular, a slight film of dust can inhibit proper adhesion. Proper use of appropriate primers can help alleviate this problem. Manufacturers’ guidelines should be consulted in every case because self-adhesive formulations are as varied as any other product discussed herein.

Caution is recommended when installing self-adhesive products. The mentality and installation techniques for self-adhesive products are more akin to those of single-ply roofing than conventional methods for installing SBS-modified bitumen membranes. The product requires some finesse and pressure during application – this is not dissimilar to the application practices required for seaming EPDM membranes with butyl tapes. As long as manufacturers, specifiers, and contractors keep this in mind, self-adhesives can be installed successfully.

Figure 2 illustrates differences in peel strength of one SBS self-adhesive material adhered to plywood with various primers. It also depicts three different self-adhesive modified bitumen membranes adhered to the HDPE surface of an underlying modified bitumen sheet.

This provides a relative comparison of the adhesive quality of the self-adhesive layer of three different sheets.

FIGURE 2



Cold Adhesive

It is common knowledge that solvent-based asphalt cutback adhesives have been used in BUR for more than half a century. It is perhaps less known that they have also been used in the United States very successfully with SBS-modified bitumen roof membranes for more than 20 years. Although it has taken time for cold adhesives to gain popularity when used with modified bitumen, momentum has shifted in recent years. For various reasons, the use of hot mopping asphalt, torching and, to some degree, even cold adhesives have become restricted. Fumes from hot asphalt kettles have prohibited this application method on many buildings (e.g., schools, hospitals, office spaces, etc.) during any period of occupancy. This either leads to scheduling work around non-occupied times or, in most cases, changing the application method altogether.

Cold adhesives are not exempt from limitations, but they are less invasive. Solvent odor can be an issue for some materials, particularly those with a high sulfur content, but the primary obstacle for cold adhesives is VOC regulations. California, specifically the South Coast Air Quality Management District (SCAQMD), has the lowest VOC regulation for adhesive used with modified bitumen membranes. Today, it stands at 250 g/L. Regulations pertaining to VOC content will become more stringent in other areas of the United States within the next few years. Proposed VOC regulations for the northeastern United States will follow the lead of SCAQMD. These changes to VOC requirements have prompted advancements in adhesive formulations. Today, this VOC level (250 g/L) is attainable while maintaining reasonable green strength and good application viscosities.

Adhesives with very low VOC levels also exist, but their current selling price (approximately five times that of typical cutback adhesives) generally makes their use cost prohibitive in the general marketplace. One such very low VOC adhesive (Low VOC Adhesive 3) was included in this study, and the data does not demonstrably support any real performance advantage compared with less expensive asphalt cutback adhesives. The only perceived advantage could be that this product, which is a moisture curing asphalt extended urethane, has better green strength in the first 24 hours than do cutback products. The long-term performance, however, is no better than less expensive adhesives.

Although it is true that solvent-based adhesives tend to soften the sheets during curing (or flash-off), with proper planning and job staging, difficulties associated with sheet softening can be minimized. Sheet softening is temporary, and results on Figure 4 illustrate the relative softness of one SBS sheet material applied with various interply methods.

In 1996, samples of a two-ply, fiberglass-reinforced, cold-adhesive-applied SBS membrane were taken from a roof assembly installed in Ohio in 1982. When tested according to ASTM D 5849 *Cyclic Joint Displacement*, the 14-year old two-ply membrane passed the requirement for newly installed membranes (500 cycles at -10°C [14°F]), far exceeding the requirement for aged materials, which is only 200 cycles. This roof membrane is still performing, 20 years after installation.

Cold adhesive is primarily composed of asphalt and solvent, plus various mixtures of fibers, fillers, and stabilizers. At the risk of sounding redundant, as with mopping asphalt, not all cold adhesives are the same. Despite generally superior bonding characteristics as compared with hot asphalt, the same quality issues must be considered. For example, is the cold adhesive compatible for use with the specified modified bitumen membrane? The choice of solvent is a major factor in this regard, as solvents vary by aromaticity, boiling point range, flash point, etc.

The base asphalt quality, together with the choice and blending of related fibers, fillers and stabilizers is also critical because of the fact that this “solids” portion of the

adhesive remains as the bonding agent when the solvent completely evaporates from the membrane assembly.

As with any laminated construction, the glue line affects the performance of the finished product. Generally speaking, thinner glue lines lead to better performance. Cold adhesive applications result in much thinner glue lines than hot asphalt applications. Most modified bitumen manufacturers ask for interply mopping weights between 20 pounds/square and 30 pounds/square (0.98 Kg/m² and 1.46 Kg/m²) or 40 mils to 60 mils (1.0 mm to 1.5 mm), respectively. For various reasons, actual interply mopping weights are often found to be in excess of these specified values. Cold adhesive interply usage is generally specified to be between 1.5 gallons/square to 2.5 gallons/square (0.6 L/m² to 1.0 L/m²), which equates to 24 wet mils to 40 wet mils (0.6 mm to 1.0 mm). After solvent evaporation, this thickness is significantly less depending on solvent content.

Most important, unlike hot asphalt that merely acts as a hot melt glue, there is a chemical bond (or type of solvent welding) that occurs when adhering modified bitumen sheets with compatible cold adhesives. Depending on the type of modified sheet and solvent system, the resultant bond is very similar to that achieved with torched or heat-welded membranes. Because of the strength of this interply bond, the chances of long-term disbonding and blister formation are greatly reduced. Even if a small interply void exists, a blister cannot grow unless the internal pressure overcomes the bond strength of the interply attachment.²

In a 1988 report by Structural Research Inc.,³ membrane factors for various SBS modified bitumen membranes were determined, including polyester, polyester/glass combinations, and fiberglass reinforced membranes. When using the same two-ply glass reinforced SBS membrane, cold adhesive and hot asphalt applications performed dramatically differently. One of the lowest membrane factors was that of the two-ply SBS membrane installed with hot Type IV asphalt, and the best performing system, of all reinforcement types, was the same two-ply membrane installed with a compatible liquid-applied cold adhesive. The membrane factor took several properties into account, including coefficient of expansion and load-strain properties at low temperature.

EXPERIMENTAL

Various tests were performed to examine the:

- Viscosity of four different liquid-applied cold adhesives.
- Peel strength of various interply attachment methods.
 - During the “curing” or “flash-off” period.
 - After heat conditioning (artificial aging).
- Softness of SBS sheet material adhered with a variety of interply materials.
- Cyclic joint displacement (fatigue) of the same two-ply, glass-reinforced SBS membrane adhered with various interply materials.

Peel Strength

ASTM D 1876 *Standard Test Method for Peel Resistance of Adhesives (T-Peel Test)* was used with the following exceptions. The sample size was 1 inch x 10 inch (25 mm x 250mm), and the jaw separation rate was 2 in./min (50 mm/min). Cold adhesive between sheets was applied with a draw-down bar at 24 ± 2 wet mils (0.6 ± 0.05 mm). Mopping asphalt was heated to 500°F (260°C) before it was poured between plies. Self-adhering membranes were rolled with a 26.0-pound (11.8 kg) roller three times back and forth. All samples were conditioned at room temperature.

Sample compositions are listed below.

- Authors' cold adhesive 1 between the authors' SBS base and SBS cap
- Cold adhesive 2 between the authors' SBS base and SBS cap
- Authors' cold adhesive 3 between the authors' SBS base and SBS cap
- Cold adhesive 4 between the authors' SBS base and SBS cap
- Authors' two-ply torched SBS membrane
- Authors' ASTM D 312, Type IV mopping asphalt (Mopping Asphalt 1) between the authors' SBS base and SBS cap
- ASTM D 312, Type IV mopping asphalt between the authors' SBS base and SBS cap
- Authors' self-adhering SBS membrane (Self-adhesive 1)
- Self-adhering SBS membrane
- Self-adhering APP membrane

Oven-aged peel strength

See above for test procedure and sample composition. Samples were conditioned at 176°F (80°C) and tested as unaged, 30, 60, and 90 days conditioned (aged).

Viscosity

All samples except the mopping asphalt were tested at 77°F (25°C), spindle 4, RPM 60, on a Bookfield DVI+ viscometer.

Membrane Softness

Interply adhesives were applied to the authors' SBS-modified bitumen membranes in a two-ply configuration just as with the other tests. Samples were conditioned for 18 hours at 158°F (70°C). Samples were allowed to cool for 10 minutes at 73°F (23°C) prior to measuring the Shore Type O durometer hardness.

Cyclic Joint Displacement (cyclic fatigue)

This test was carried out using *D5849-95 Standard Test Method for Evaluating Resistance of Modified, Bituminous Roofing Membranes to Cyclic Joint Displacement* under test condition # 4. Samples were adhered to solid wooden supports using epoxy glue. Samples were conditioned for 24 hours at room temperature. Sample composition consisted of two plies of the authors' (1.5 lb/100 ft.²) 75 g/m² fiberglass reinforced SBS membrane.

Heat Conditioning (oven aging)

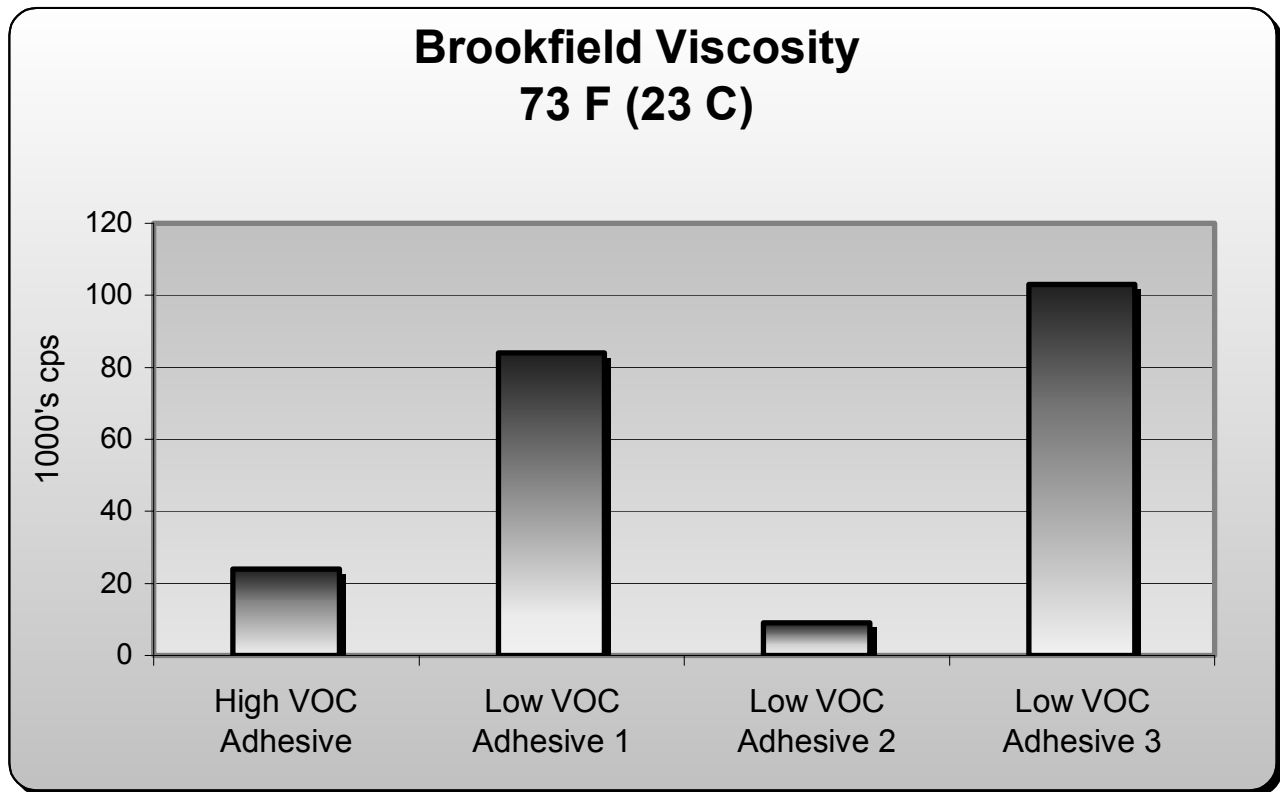
Samples were conditioned for 30, 60, and 90 days at 176°F (80°C).

RESULTS

Viscosity

Viscosity of four cold adhesives was measured. The high VOC adhesive and the low VOC Adhesive 2 are known to apply easily using squeegee, spray or extrusion equipment. The viscosity results in Figure 3 support field experience. Due to their relatively high viscosity, achieving the desired interply usage has proven difficult when using low VOC Adhesives 1 and 3.

FIGURE 3



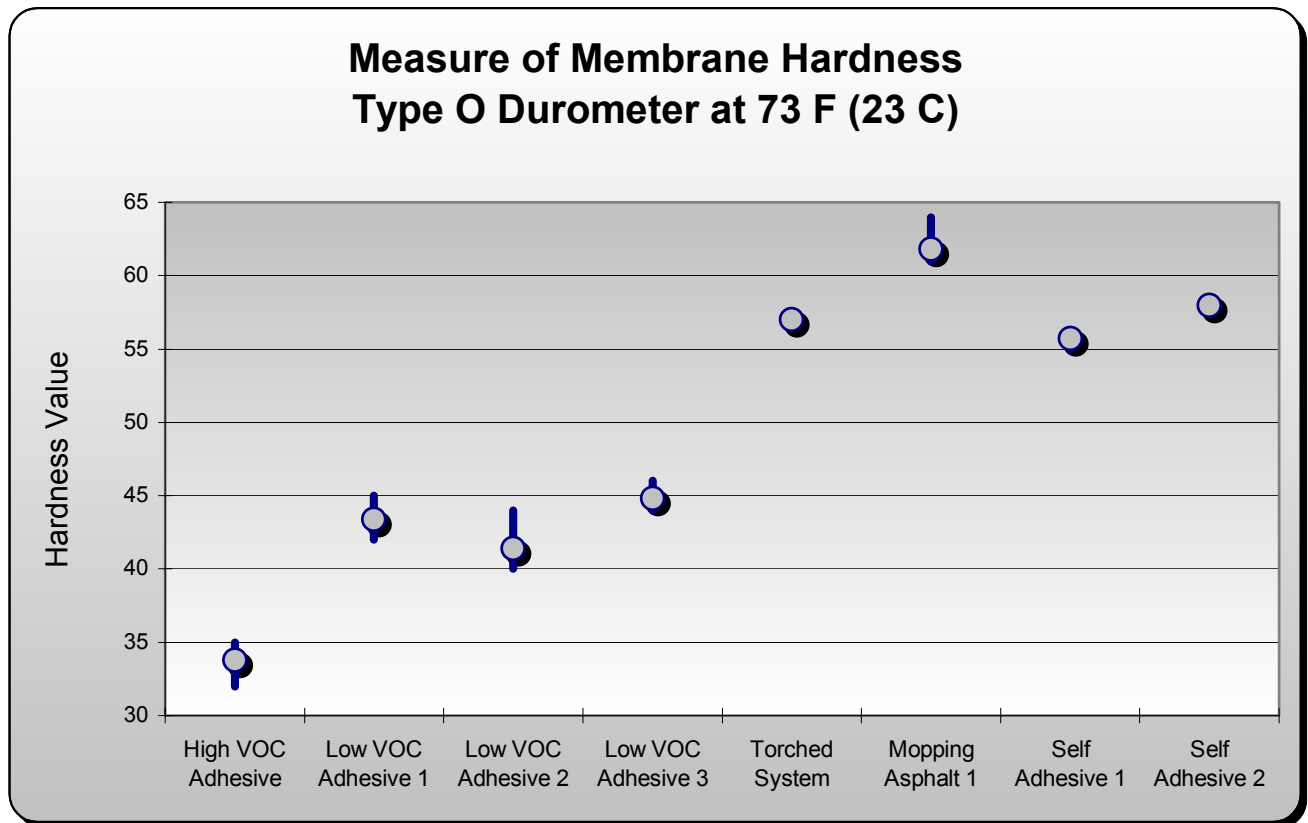
Sheet Softness Using a Type O Durometer

Three distinct groupings of softness can be drawn from the data. The same SBS sheet materials were prepared using four different liquid adhesives, torch, mopping asphalt, and self-adhesive. In order of increasing softening effect, they can be ordered as follows:

- Non-solvent application methods (torch, mop or self-adhesive)
- Low VOC adhesives (from 15 g/L to 250 g/L showed virtually the same result)
- High VOC adhesive (> 350 g/L)

This sheet softening condition was temporary and the membrane returned to its “normal” hardness after some time on the rooftop, usually several weeks to a few months depending on the drying conditions.

FIGURE 4



Peel Strength Testing

Two separate issues were evaluated. The first was the green strength, or bond strength, within the first few days of application of cold adhesive. See Figure 5. The second issue was the ultimate bond strength of various attachment methods when tested unaged and conditioned (aged) for 30, 60, and 90 days at 176°F (80°C). See Figure 6. The authors' company experience has shown a reasonable correlation to the above conditions as follows.

- 30 days is approximately equivalent to 10 years in the field.
- 60 days is approximately equivalent to 20 years in the field.
- 90 days is approximately equivalent to 30 years in the field.

This is, of course, dependent on many variables, such as geographic location of the building, building design and use, rooftop construction, etc.

FIGURE 5

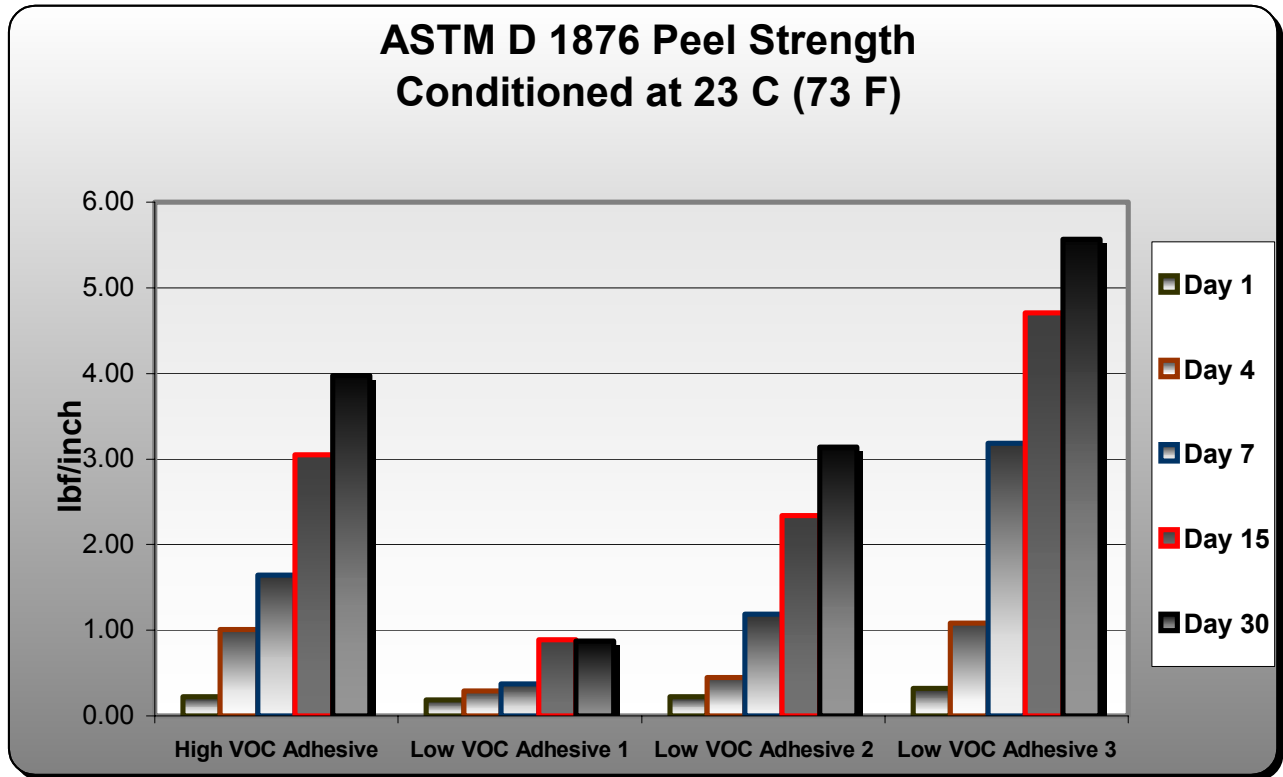
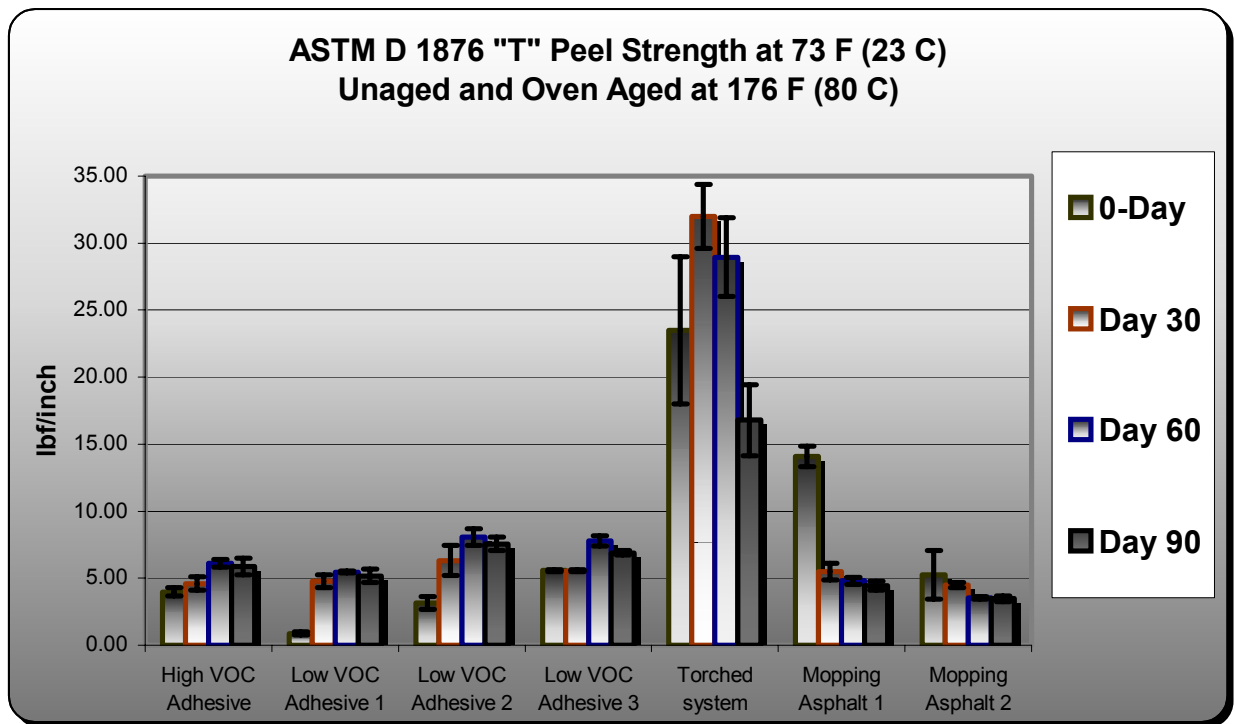


FIGURE 6

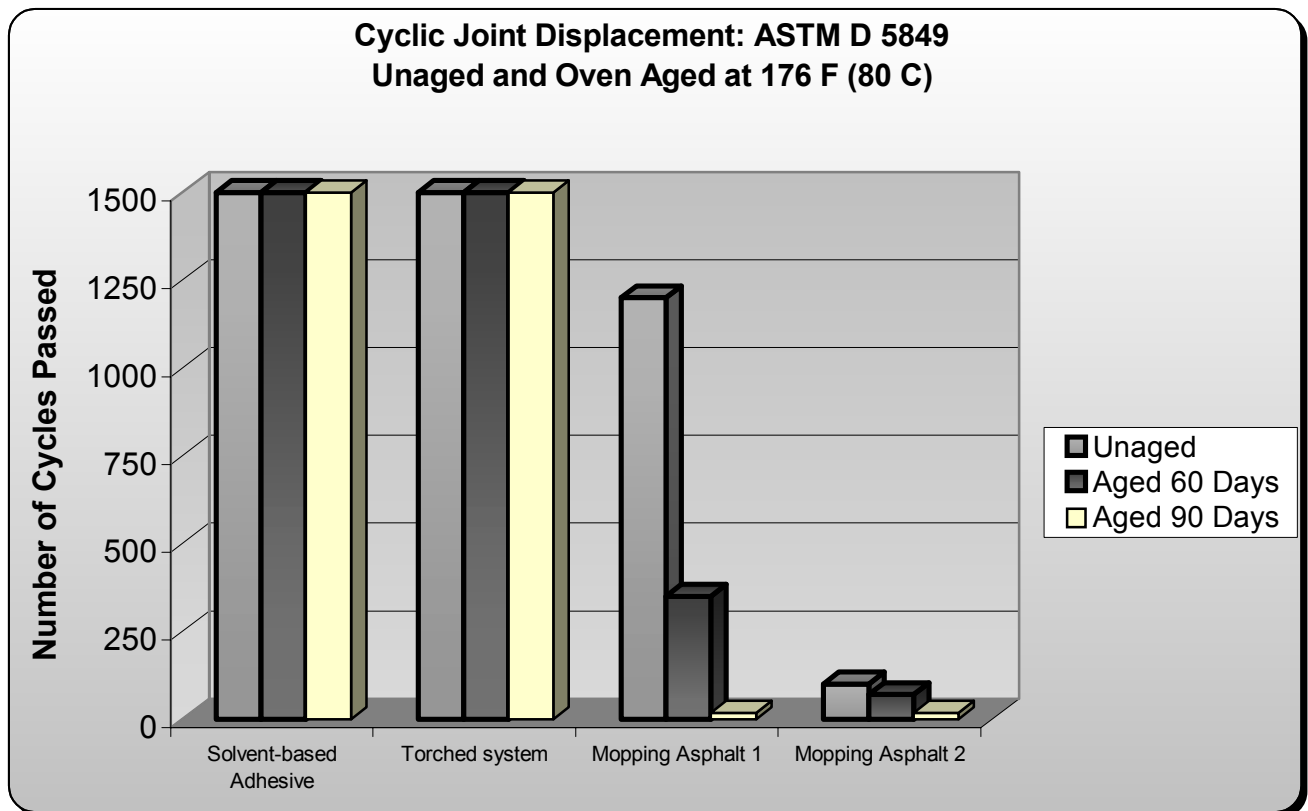


The data shows that, as discussed in the body of the document, torching maintains the best bond strength because of the fusion of two sheets into one. Cold adhesives fair very well over this 30-year aging equivalency as well. Oxidizing mopping asphalt embrittles and steadily loses bond strength over time. The data also shows a distinct difference in two different sources of oxidized mopping asphalt. Insufficient data existed at the time of this writing to comment on the long-term performance of self-adhesive membranes.

Cyclic Joint Displacement (Cyclic Fatigue)

The data, which, in the authors' opinion, is a good overall indicator of long-term performance, shows that solvent-based adhesives and torching are far superior in maintaining their bond integrity over time when compared with oxidized mopping asphalt. See Figure 7.

FIGURE 7



CONCLUSION

When either cold adhesive or torching is used for membrane application instead of hot oxidized asphalt, a unique set of parameters is introduced. Torched and heat-welded multi-ply modified bitumen applications result in a truly monolithic membrane. Modified bitumen sheets applied with cold adhesive become effectively monolithic and perform accordingly. This can be demonstrated simply by trying to separate cured, cold-applied modified bitumen plies after conditioning in a freezer. Core cuts of modified bitumen sheets bonded with Type III or IV asphalt can be easily separated by hand at temperatures approaching 32°F (0°C). Most cold-adhesive-applied membranes, however, cannot be separated at temperatures approaching -40°F (-40°C).

Because of this tenacious interply bond strength, cold adhesive and torched/heat-welded membrane systems exhibit superior fatigue resistance, coefficient of expansion, bond strength, and rooftop performance as compared with oxidized asphalt-applied membranes. Figure 7 illustrates the Cyclic Joint Displacement results of identical two-ply SBS, glass-reinforced membranes bonded with different interply attachment methods: cold adhesive, torch and two ASTM D 312 asphalts as shown in Figure 1. Just as in Figure 1, the membranes were tested before aging, and after the heat aging equivalent of 20 years and 30 years of field exposure.³ As mentioned earlier, this test is typically terminated after 500 cycles, but the cold-applied adhesive and torch-applied membranes were taken to 1,500 cycles without failure. Neither membrane rupture nor interply disbonding was observed.

When long-term performance is paramount, it is easy to see the advantages that cold adhesive and torched/heat-welded applications have to offer.

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