Adhesives for the Installation of Single Ply Roofing Membranes

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Abstract

The presentation will begin with a review of the general requirements for adhesives for the installation of single ply roofing membranes and a description of the general advantages and disadvantages of solvent based versus water based adhesives.

This will be followed by a review of the specialized adhesive requirements of 5 types of single ply roofing membranes.

The third section will describe the installation of Felt Backed Rubber membranes with a wet set type of solvent-based adhesive, followed by a description of the procedures for installing Plasticized PVC membranes with a special solvent-based type contact cement and a wet set water based adhesive. This section will review relevant issues relating to these different situations.

The last section will present and discuss some recent laboratory tests relating to accelerated weathering of Plasticized PVC membranes bonded with some water-based adhesives and two felt backed PVC membranes bonded with water based adhesives.

This paper should be of considerable to adhesive chemists, as well as to architects, specification writers and people responsible for building maintenance.[1]

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INTRODUCTION :- The intention of this paper is to review the performance requirements that adhesive formulators must address, in order to develop truly functional adhesives for use with roofing membranes. This information should also be of considerable interest to architects, specification writers and people responsible for building maintenance.

First of all, since roofing is installed outdoors a wide range of weather conditions can occur. The temperature, humidity and wind velocity can dramatically affect the working characteristics of the adhesives. Some adhesives might work very well on a cool, still day, but dry so fast on a hot, windy day that the installers could not work fast enough to get a bond. The most useful adhesives will have a balance of properties that will allow them to be used successfully under the widest possible range of conditions.

GENERAL CONSIDERATIONS :- The first item to consider is the ease of spreading the adhesive over a large area, under all sorts of weather conditions. Methods for applying the adhesives can include rollers, sprayers, squeegees, brushes and trowels.

The amount of adhesive applied has a significant impact on the performance. It is important that the recommended amount of adhesive can be easily applied to a uniform thickness.

A long “Open Time” window is very desirable. (The “Open Time” is the time after application of the adhesive to the substrate that the membrane can still be successfully bonded.) Longer Open Times can allow for temporary hold ups in the installation, without sacrificing the bond performance.

The requirements for easy spreading and long Open Times can seem to be contradictory to the desire for an immediate strong bond, in order to prevent problems with uplift due to wind. This is because the volatile components which make the adhesive easy to spread and which can help with the initial wetting and adhesion to the membrane must completely disappear before the adhesives can develop their full strength.

Of course the adhesives must adhere well to the widest possible range of roofing substrates. Some roofing substrates are porous (e.g. wood and concrete) while others such as metals are not. Porous substrates allow for the use of “wet set” adhesives, since the remaining volatiles can dissipate through the porous substrate. On the other hand non-porous substrates require the use of either Contact Cements or a Pressure Sensitive Adhesive approach.

As mentioned, once the membrane is laid into the adhesive a strong, immediate bond is desirable, since weather conditions are not under the control of the installer.

On the way to the job site the adhesives should have good storage stability, be freeze thaw stable, resistant to biological attack in the can, not separate irretrievably and not turn into an unspreadable gel.

Once the membrane has been successfully bonded the adhesive must continue to perform. It must not become brittle or weak as the installation ages and the assembly is subjected to the temperature extremes that any roof in Canada can experience. As the roof assembly ages the adhesive must retain its’ peeling and its’ shear strength. The membrane protects the adhesive from attack due to weathering. Therefore it is not as subject to weathering and oxidation attack as the membrane itself. As will be discussed in more detail later, the adhesive may be subject to deterioration due to attack by some of the materials in certain types of membranes.

Although the membranes are supposed to keep water out it is important that the adhesive bond not be destroyed by water. This ensures that a minor leak does not become a major catastrophe.

Of course all of these properties should be achieved at a reasonable cost. (This is the factor that differentiates a commercially successful adhesive from a fantastic adhesive with little or no sales volume.)

In general solvent based adhesives are typically fast drying, water resistant and can be used on both porous and non-porous substrates. On the other hand they present dangers to the installers due to flammability, toxicity of the solvent vapours and air pollution. In general the solids content of solvent-based contact cements ranges from 18 to 23% by weight. Obviously the bulk of every such pail used on a roof ends up as air pollution.

In the case of water-based adhesives the advantages include non-flammability, low toxicity and minimal air pollution. On the other hand they typically suffer from being slower to dry or set, especially under cool, humid conditions, are more prone to be water sensitive, are typically not

suited for use on non-porous substrates and can be sensitive to damage by freezing, either in the pail or before the adhesive layer has dried completely.
Nevertheless, the safety and environmental problems with solvent based adhesives provide a strong motive for adhesive and polymer chemists to continue to improve water based adhesives for these applications.

ISSUES WITH SPECIFIC TYPES OF MEMBRANES

Felt Backed Rubber :- These membranes have a non-woven type of felt which has been factory bonded to one side of the rubber sheet. These membranes can be installed with Hot Asphalt type, solvent based rubber/resin type or water based adhesives. (Note that it is possible to create a non-woven fabric which is water repellant and therefore not well suited to use with water based adhesives.)
The usually absorptive nature of the felt backing means that "wet set" adhesives can be used to easily give good bonds to the felt. This is the one type of membrane where solvent-based rubber/resin mastics can be used. As mentioned before the membrane does provide some protection from attack on the adhesive. It is important to note that the rubber that is commonly used in these adhesives is Styrene Butadiene. This type of rubber is easily degraded by oxygen and ozone. The polymerization can also leave some batches of the polymer subject to further crosslinking when subjected to higher temperatures for long time periods. This process can turn a rubbery material into a powder. Prevention of these conditions requires the use of special stabilizer additives. Use of adhesives other than the tested and approved ones can lead to bond failures.

Plasticized Polyvinyl Chloride Membranes :- Polyvinyl Chloride (PVC) is a rigid material at normal temperatures. In order to make it flexible enough to handle at low temperatures the use of special plasticizers is required. The plasticizers that make the PVC flexible can migrate from the membrane into the adhesive. This can lead to the membrane becoming stiffer, or more brittle (esp. at lower temperatures.) and to the adhesive losing its' cohesive strength. There can also be problems relating to shrinkage of the membrane, due to loss of volume. Another problem is that the special stabilizers which are necessary to make the PVC useable outdoors for long time periods are often more soluble in the plasticizers. Therefore if the plasticizers move from the membrane into the adhesive there is less protection at the surface of the membrane. This can lead to a significant reduction in the service life of the membrane. Working with PVC membrane manufacturers we have found that it is possible to conduct a simple, accelerated laboratory test to measure the % weight loss of plasticizers from the membranes into the adhesive layer.
Adhesives which absorb from nil to 1 % by weight of the membrane have been found to correlate very well with excellent long term results in actual installations, in a wide range of conditions.
Some adhesives can absorb up to 5 % by weight and still retain their bond integrity. However, some membranes bonded with these adhesives can show signs of discolouration of the membrane within 6 months to one year of their installation, in Canadian locations.
A few polymers that have low plasticizer absorption can be formulated to provide excellent adhesion to plasticized PVC. Even with these polymers the other ingredients used to prepare the adhesives can have a detrimental effect on the degree of plasticizer absorption and its' effect on the strength of the adhesive. Since different membrane manufacturers can utilize a range of plasticizer types it is important to use only those adhesives that have been specifically tested and approved for use with the membrane to be installed.
Ignoring this advice can lead to loss of adhesion within a time frame of a few months to 2 to 3 years. Other problems such as membrane shrinkage, loss of flexibility, and early weathering can also occur.
Both water based wet set adhesives and solvent based, specialty contact type cements exist which can be successfully used with a wide range of plasticized PVC membranes.

EPDM Membranes: - The excellent weather resistance of Ethylene Propylene Diene Monomer (EPDM) rubber makes it an excellent choice as a polymer for an exposed application such as roofing. However, like polyolefins the low polarity of its' surface makes it one of the most difficult membrane materials for achieving a good bond strength. Unlike PVC membranes where a poor choice of adhesive may not be obvious right away, you will likely know at the time of the installation that there is a problem. In some ways this is a better problem. This should minimize the risk of having large areas of membrane installed, that later turn out to be a major headache. As with plasticized PVC there are functional adhesives for EPDM membranes on the market. The ones that I know best are specialized solvent based contact cements. I should stress that there are many general-purpose contact cements available that simply do not bond to EPDM. As with the other types of membranes the best approach is to use an adhesive that has been tested and approved by the membrane manufacturer.

Hypalon Membranes: - These are chlorosulfonated polyethylene membranes. Although you see the word polyethylene in the name, it is much easier to bond to these membranes. The chlorosulfonation renders them much more polar. As a consequence a very wide range of solvent-based contact cements provide good bonds to Hypalon. The special adhesives that work well with EPDM typically also work well with Hypalon. Therefore many installers can carry the one grade of adhesive for both types. This minimizes the risk of using the wrong adhesive for an EPDM membrane.

TPO Membranes: - Thermoplastic Polyolefin (TPO) roofing membranes are based on a wide range of polypropylene and ethylene-propylene type, copolymerized rubbers. These copolymers are designed to have low glass transition temperatures. This is important so that they maintain their flexibility at the lower temperatures encountered in some climates, without the use of low molecular weight plasticizers. As a result there are no problems associated with the movement of significant amounts of low molecular weight components. Of course, polyefins are not completely weather resistant. Therefore these types of membranes must be compounded with additives designed to enhance their weather resistance. Of course this type of polymer exhibits a low energy surface. As a consequence, with these types of membranes, good adhesion is difficult to achieve. As is the case with EPDM membranes bonding problems are typically observed at the time of installation. Although TPO and EPDM membranes are somewhat related chemically, they typically require the use of different adhesives. (Note that EPDM membranes typically contain Carbon Black reinforcing filler and have residual talc, or other mould release agent on the surface.) TPO membranes typically are light coloured and do not contain Carbon Black. Many manufacturers produce both EPDM and TPO membranes. It has been necessary for them to carry separate adhesives for each type of membrane. As with EPDM the common type of adhesive for TPO is a flammable, polychloroprene based Contact Cement that has been specifically formulated for the best possible adhesion to TPO.
With careful selection of ingredients we have recently found that it is possible to create a Contact Cement that can provide commercial levels of adhesion to both TPO and EPDM membranes. We have also been able to do the same with an acrylic latex based, Pressure Sensitive Adhesive. The latter represents a much safer and more environmentally friendly adhesive. In both cases the new adhesives are more expensive than existing products and so have not enjoyed significant commercial success. Nonetheless they demonstrate that such products are feasible.

INSTALLATION RECOMMENDATIONS

In this section we review some more specific aspects of the recommended procedures for installing two types of roofing membranes.

Felt Backed Rubber: - As mentioned earlier these membranes can be installed with asphalt, solvent or water based adhesives. Today we will focus on the use of a particular type of solvent based adhesive. These are sometimes referred to as “Cold Adhesives” and sometimes as Mastics. The term “Cold Adhesive” refers to the contrast between using these adhesives at ambient temperatures, rather than the typical 360 to 400 degrees Fahrenheit used with hot asphalts.

As in any successful installation the deck must be smooth, clean, dry, sound and free of any loose dust, dirt, grease, oil, asphalt or sharp debris. If the insulation is on top of the deck it should be dry and covered with a protection board system that also meets the criteria listed above. The membrane is then laid out on the deck. The membrane is then folded back about ½ way and adhesive is applied to the exposed deck. A paint roller is used to apply five 8x8 inch squares of adhesive for every square yard of membrane. The adhesive should be allowed to dry for about 5 minutes before the membrane is carefully rolled into the wet adhesive.
The second roll is then positioned to give the proper overlap for seaming. It is then folded back half way and the first roll is folded back onto the portion that has already been bonded. The adhesive is applied in the same way and the procedure is repeated.
The next step is to seal the seams, flashing, parapets, eaves, drains, and vents etc. This requires the use of a seaming paste and flashing adhesive. The general requirements discussed earlier apply to these adhesives as well.

<u>Plasticized PVC Membranes</u>: - The previous comments about deck preparation also apply here. Poor preparation is related to many of the subsequent problems that occur. Since a roofing failure can lead to considerable damage it really is worthwhile to invest the time to properly prepare the deck.
We will consider two different types of adhesives for installing plasticized these types of membranes.
The first is a special type of solvent-based contact cement. This is formulated with a different type of polymer (i.e. Not a polychloroprene) that gives the necessary resistance to plasticizer migration resistance. The temperature and humidity must be such that no condensation forms over the adhesive layer. Typically installations can proceed at temperatures approaching 0 degrees C. As with the felt backed rubber the membrane is laid out on the deck. Then one third of it is rolled back onto itself. At this point a roller or brush is used to apply between ½ to 2 gallons of adhesive per 100 square feet, onto the deck. This wide range of coverage reflects the differences in porosity, or absorbancy, of substrates. For example plywood or trowelled concrete would typically require the least, whereas a substrate such as Perlite board would require a much greater quantity of adhesive. The important point is to have a layer of adhesive above the surface of the deck. (This is important so that the adhesive on the back of the membrane can fuse with that on the deck, when the two layers are brought into contact with one another.)
Note that adhesive should not be applied at the seams.
Then apply the same adhesive, in the same manner, to the back of the folded back portion of the membrane. By now the adhesive on the deck should be well on its' way to being dry. When the adhesive on the deck is fully dry and that on the back of the membrane is just tacky to the touch, roll the folded back portion carefully into position and press into contact. The word carefully should be stressed, since this is contact type cement and there is an immediate bond. The ultimate bond strength is achieved over the next 24 to 72 hours.
Next fold back the other 2/3 of the section of membrane and repeat the process. The procedure is repeated with the remaining sections of membrane. The seams can then be sealed. The same adhesive can be used, but more often the thermoplastic nature of this type of membrane is utilized. This means that the seams can be heat welded. A special hand held hot air gun can be used. On larger jobs a special, automated heat-welding machine provides excellent results. Again the details around parapets, etc are finished and the installation is complete.

The approved water based adhesive can be used on porous decks such as wood or concrete. The membranes are installed while the adhesive still contains water. Since the membrane is impervious to water it is crucial that the deck be able to absorb the water and transport it away from the interface. This means that painted, or otherwise sealed, wood or concrete is not a suitable substrate. The preparation comments are the same as those described earlier. It is also important to note that the installation should be at 10 degrees C or higher and that the Dew Point be such that evaporation of water is possible. This limits the use of these more environmentally friendly adhesives, in terms of the types of decks and weather conditions.
As with the solvent based adhesive the membrane is laid out on the deck and 1/3 is rolled back onto itself. The adhesive is applied to the deck with a roller or a notched trowel or squeegee at a

rate of 1 to 2 gallons per 100 square feet of membrane. Do not apply adhesive at the seams. Within 5 to 10 minutes of applying the adhesive to the deck, roll the membrane into the wet adhesive. Note that there was no need to apply adhesive to the back of the membrane. Unlike the solvent based adhesive one does not wait for the adhesive to dry. Unlike the solvent-based adhesive it is possible to reposition the membrane if necessary. In fact one should be able to carefully peel back a portion of the freshly installed membrane and see that there is now wet adhesive on both the deck and the back of the membrane. If there is no adhesive on the back of the membrane there was either not enough adhesive applied, or the installer waited too long. In the former case the membrane can be rolled back and more adhesive can be applied. In the latter case the dried layer of adhesive typically presents a problem of a surface that is no longer smooth. Furthermore the surface is now partially sealed and so less able to dissipate the moisture if another layer of adhesive is applied. In this case it may be necessary to partially scrape away some of the excess, before applying more adhesive. Obviously it is preferable to avoid such a situation, by establishing the application rate and drying time for the specific site conditions, at the beginning of the job.

Note that the application of too much adhesive would tend to float the membrane so that it would not stay in position, the drying time would be far too long and there would be only a very weak initial bond.

Note that the water-based adhesive is obviously not suitable for use as a seaming adhesive. In this case it is imperative to use the heat welding process. The finishing steps are essentially the same as those for the other systems. The exception to this is that non-porous substrates such as metal flashing may be encountered. In such cases it is necessary to utilize the special solvent based contact cement for these finishing details.

ARTIFICIAL WEATHERING TEST RESULTS WITH 2 TYPES OF MEMBRANES

Introduction

In this section we will review some laboratory test results on bonded assemblies of two types of membranes. In the first case we will examine the effects of 3 different commercial adhesives on the accelerated weathering of two commercial PVC membranes, with 2 colours for each type. Comments on actual field observations versus lab results will be made.

A similar set of test results with 4 adhesives and two lower cost, fabric backed PVC membranes will also be examined.

Experimental

Pieces of ¼ inch Luaun mahogany plywood were precut to a size suitable for use in a QUV artificial weathering device. Pieces of the various membranes were precut to the same size. A 1/16 by 1/16 inch V notch trowel was used to apply the various adhesives onto the plywood pieces. The membrane pieces were pressed into the wet adhesives after a waiting time of 10 minutes. The assemblies were rolled with a rubber-covered roller to ensure uniform contact. The bonded assemblies were left on the laboratory shelf for 4 days before being positioned in the QUV apparatus. A variety of different bulbs can be used in the QUV. For these tests we used UVA 351 bulbs.

For the tests with the PVC membranes two colours of membranes from each of two different manufacturers were used. A set of 3 different adhesives was used to prepare bond assemblies with these membranes. Adhesive sample A was one that has been used for many years with membrane B. There have been some installations, with this combination, that have exhibited some slight fading and or weathering. In these cases the visible surface effects have been correlated to areas of an excess of adhesive under the membrane. Measurements of the amount of weight loss from these types of membranes into the adhesive layer have typically been in the range of 5% of the weight of the membrane. It is well known that PVC is fundamentally unstable to weathering. However, it is possible to formulate plasticized PVCs that are very stable outdoors. Unfortunately the stabilizers that allow the PVC to be used outdoors are often more compatible with the plasticizers. Therefore if too much of the plasticizer is removed from the PVC there can also be a loss of the necessary stabilizers. Adhesive C has been used with membrane A for over

two decades with essentially no complaints about discolouration or weathering problems. This combination can therefore serve as a positive control for reference purposes. Note that adhesive C has essentially no plasticizer absorption from these types of membranes. Adhesive B is a somewhat newer adhesive that has been used to some extent with both of these membranes. It has a plasticizer absorption of only about 0.2 to 1 % by weight, from the same PVCs. It would be expected to provide better weathering resistance than adhesive A. It is also cheaper than adhesive A, but has not displaced formulation A since most installers do not like the short open time window and the fact that it can not be reactivated with heat.
The bonded assemblies were subjected to exposure in the QUV for a total of 10 weeks. The appearance of the samples was monitored on a weekly basis. In this series the changes occurred slowly. Even after 10 weeks of accelerated ageing only one assembly showed any significant change. Five of the assemblies did not change, as compared to unexposed control samples. The overall results were as follows,

		Adhesive A	Adhesive B	Adhesive C
Membrane A	Light Gray/Brown	Very Sl. Fading	Very Sl. Fading	Sl. Yellowing
Membrane A	Mottled Gray	No Change	No Change	Sl. Yellowing
Membrane B	Medium Brown	No Change	No Change	Very Sl. Yellowing
Membrane B	Mottled Gray	Very Sl. Yellowing	No Change	Yellowing

The supplier of the B membranes above was facing competition from much lower cost, thin gauge, felt backed PVC membranes. The surface appearance of the latter products is very much like that of the high quality PVC products. A decision was made to develop a felt backed PVC product that would provide a lower cost option, but at a better quality level than the low cost membranes. As part of the process of evaluating adhesive candidates for this new membrane accelerated weathering tests were carried out with this new membrane and one of the low cost competitive membranes. These membranes were bonded with 4 adhesives. Adhesives A and B from the first set were used, as well as two other adhesives, labeled D and E. The latter two were chosen because another supplier had recommended them for use in this application. From earlier tests of these two adhesives with plasticized PVC floorings it was known that adhesive D typically had a moderate absorption of plasticizers and that E seemed to have a higher affinity for plasticizers. These assemblies were subjected to a total of 4 weeks of exposure in the QUV.
In this series some of the samples began to change after much less exposure. This test series was terminated after only 4 weeks. By this time one assembly was severely discoloured. The overall results were as follows,

	Adhesive A	Adhesive B	Adhesive D	Adhesive E
Prem. Quality Membrane	Very Faint Yellowing	No Change	No Change	Yellow
Lower Cost Membrane	Some Yellowing	No Change	No Change	Severe Yellowing

<u>Conclusions</u>

The first set of results was not completely consistent with the hypothesis that weather resistance can be correlated with the amount of plasticizer absorbed from the PVC into the adhesive. They also demonstrated that there can be differences in performance within one company's' product line. This may be due to the effects of different colourants or variations from batch to batch. As mentioned above we know from field experience that the combination of membrane B and adhesive A has exhibited some minor problems. However, by using the known field results as a standard one can at least compare the behavior of any new adhesives to established combinations. Provided that the results are as good, as or better than, the control the new combination should be acceptable.
In the second set of results the correlation between plasticizer absorption and weathering seems more straightforward. As expected there were no observed changes with adhesives B and D. As expected adhesive A showed some slight effect and adhesive E was detrimental to both

membranes. It is not possible to measure the weight loss of plasticizer from the felt backed membranes into the adhesives, since it would not be possible to cleanly separate the membranes from the adhesive layer. However, it is assumed that similar types of plasticizers would be used and that the relative weight losses would be comparable. It is also assumed that similar stabilizers would be used and that the movement of plasticizer would be accompanied by the movement of stabilizers. In the lower cost products it is likely that the use of expensive stabilizers would be kept to the lowest possible level. Therefore it seems reasonable that these lower cost products would be more sensitive to the loss of stabilizer.

The difference in quality between the two felt backed membranes is obvious. The difference between the felt backed and the PVC membranes is also obvious when one considers that the colour changes showed up in much less time. There were no observed changes with either of the felt backed membranes and adhesives B or D. This is consistent with the comments above about the effects of plasticizer, and therefore stabilizers, being more obvious in the lower cost products.