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Comparing Self Adhering Flashing Tape Adhesives

ABSTRACT:

Pressure sensitive adhesives (PSA) tapes are used in a broad spectrum of applications to adhere materials together and/or seal environments from each other. PSA adhesive technologies are based on acrylics, silicone and rubber chemistries. Rubber based adhesives are still the most widely used and can be further subdivided into synthetic and natural rubbers. Rubber based adhesives are typically composed of rubber (elastomer), tackifier, filler plasticizers, curatives and stabilizers.

Butyl rubber based adhesives have been used for over 50 years as adhesives to protect oil, gas and water transmission pipelines from the rigors of pipeline installation and corrosion. So it is quite natural to use butyl rubber based PSA in the construction industry. For flashing applications, these systems feature the added benefit of a “peel and stick” type installation for ease in handling.

In this paper we will present laboratory data that compares butyl rubber PSA flashing tapes to asphalt containing flashing tapes. We will present data that compares adhesion to construction substrates (initial and after aging), as well as performance comparisons at various environmental exposure test conditions.

Our test results against show that the butyl based flashing tapes exhibit comparable or adhesion performance, greater functionality after elevated temperature exposure, and superior shear and UV resistance.

These tapes may be manufactured with a variety of backings including foils and films.

KEYWORDS:

Flashing Tapes

Rubberized Asphalt

Butyl Rubber

Pressure Sensitive Adhesive (PSA)

Construction

Pipeline

Introduction

For over 50 yrs butyl pressure sensitive adhesives (PSA) have protected oil, gas and water pipelines from corrosion. Our butyl based tapes can be applied at the installation site, over the ditch of a variety of climates or plant applied under controlled conditions. One of the features of butyl PSA is extremely long term stability and excellent barrier properties.

Our technical service team has periodically conducted bell hole testing to verify functionality of coating. A bell hole is where the pipe is unearthed and the pipe surface inspected. The protective coating is chiseled off, and coating is inspected for integrity. In fact, the areas of that were inspected and repaired with the same butyl adhesive. We have had great success with these systems, as evidenced by the fact that after 50 years the PSA is still pliable, conformable and still able to seal the pipes surface!

Another attribute of these butyl PSAs is that the material is self gasketing due to its ability to cold flow into the textured surface of pipe. Furthermore, the spiral void of the tape formed during the wrapping process and overlap is also sealed by this adhesive.

Although these tapes are applied to pipes which are then buried underground, they can be exposed to severe outdoor weather conditions. In fact in some applications, the coatings remain exposed from a few weeks to several months before burial.

It is for the reasons above that we feel that flashing systems using butyl based adhesives are an excellent fit to the building and construction industry. The outdoor exposure time of the pipewrap systems described above could easily be comparable or even exceed exposures at building construction sites, where tapes may be exposed before being covered with siding or shingles.

Furthermore, we have in our portfolio of products a tape that is applied under water to steel pilings. That same adhesive is used in some of our construction products. Scuba divers wrap the pipe after scraping barnacles from the steel pilings and apply the tape. After several weeks, the unwrapped section was corroded whereas the wrapped piling was pristine and there was good adhesion.

In this paper, our objective was not to single out competitive products, but rather to group together similar products and show the difference between rubberized asphalt (RA) versus butyl adhesive systems. The study shown below is the results of our preliminary effort. Indications based on performance testing are that butyl PSA provides more consistent adhesion, and longer lifetime and less frequent repair or replacement of flashing systems due to failure.

Background

To understand the function of both asphalt and butyl adhesives in a window or roof flashing application, it is beneficial to talk about the chemistry of both systems and the attributes and shortcomings of each.

Because asphalt is a more established technology and butyl adhesive is a relatively new player in this arena, we will discuss asphalt first. Most of us are familiar with asphalt being used in road paving and roofing shingles.

Chemical & Engineering News (Copyright © 1999 American Chemical Society) [1] provides the following description of asphalt materials:

> *The American Society for Testing & Materials defines asphalt as a dark brown to black cementitious material in which the predominating constituents are* ***bitumens*** *that occur in nature or are obtained in* ***petroleum processing****. Bitumen is a generic term for natural or manufactured black or dark-colored solid, semisolid, or viscous cementitious materials that are composed mainly of high molecular weight hydrocarbons. The term includes* ***tars and pitches derived from coal****.*

"Almost all asphalt used today is derived from the ***bottom of the barrel*** *– that is, the last cut in the petroleum refinery after naphtha, gasoline, kerosene, and other fractions have been removed from crude oil," Usmani tells C&EN. "Very little is produced from other natural resources."*

Asphalts are highly complex and not well-characterized materials containing ***saturated and unsaturated aliphatic and aromatic compounds*** *with up to 150 carbon atoms. Their composition varies depending on the source of crude oil. Many of the compounds contain oxygen, nitrogen, sulfur, and other heteroatoms. Asphalt typically contains about 80% by weight of carbon; around 10% hydrogen; up to 6% sulfur; small amounts of oxygen and nitrogen; and trace amounts of metals such as iron, nickel, and vanadium. The molecular weights of the consistent compounds range from several hundred to many thousands.*

The compounds are classified as ***asphaltenes or maltenes*** *according to their solubility in hexane or heptane. Asphaltenes are high molecular weight species that are insoluble in these solvents, whereas maltenes have lower molecular weights and are soluble. Asphalts normally contain between 5 and 25% by weight of asphaltenes and may be regarded as colloids of asphaltene micelles dispersed in maltenes.*

Many of the compounds in asphalt are polar since they contain alcohol, carboxyl, phenolic, amine, thiol, and other functional groups. As a result of this polarity, the molecules self-assemble to form multimolecular clusters with molecular weights up to 100,000. The adhesion of asphalt to aggregate is also thought to depend on the polar attraction between molecules in asphalt and the polar surfaces of aggregates.

"Asphalt has a polymer-type network that is unique," Usmani says. Although ***not a polymer*** *in the strict sense of the word,* ***it is a thermoplastic*** *material—it softens when heated and hardens upon cooling. Within a certain temperature range an asphalt is also viscoelastic, which means that it exhibits the mechanical characteristics of viscuous flow and elastic deformation.*

Although asphalt has been around for millions of years in crude oil, ***it doesn't last forever when used for paving roads.*** *Few of us can have missed jolting over cracks and ruts in heavily trafficked roads.*

A number of factors impinge on the performance of asphalt. These include its composition and the crude oil source, the type and amount of aggregate used, the presence of moisture, the method of road construction, temperature, and, of course, the volume of traffic.

Ideally, asphalt used for paving roads should remain viscoelastic in all weather conditions. However, many asphalt roads soften in summer and suffer from rutting, or permanent deformation, as it is also called. ***At low temperatures****, neutral molecules in asphalt arrange themselves into more organized structural forms. As a result,* ***the material hardens, becomes brittle, and cracks*** *under the stress of heavy traffic loads. This is known as thermal and fatigue cracking.*

Asphalts also lose their plasticity and therefore ***harden and crack or crumble when*** *they lose their more volatile lower molecular weight constituents or when these constituents are oxidized. This process is known as aging. Moisture from rain and other sources can also invade and damage asphalts, particularly aged or oxidized asphalts because they have* ***a larger number of polar constituents to attract water molecules*** *[1].*

The thermosplastic, viscoelastic properties of asphalt seem to make this material a desirable component for construction adhesives. In addition, because it is largely a “by-product” of petroleum refining, it would tend to be inexpensive. However, the discussion above indicates that it is a variable raw material that is susceptible to attack by moisture and oxidation; and is adversely affected by cold temperatures.

In butyl rubber based PSA, the major component is the butyl and below is a discussion of its properties [2]:

> *Butyl rubber, also known as polyisobutylene is a synthetic rubber or elastomer. It was first developed in the 1940’s by German chemists and commercialized in 1943.*

The typical composition of butyl rubber is approximately 98% polysiobutylene, with the balance being isoprene. The isoprene units contain a double bond that provides a site for crosslinking during vulcanisation and are located randomly in the polymer chain.

Halogenated butyl rubbers such as chlorinated (chlorobutyl) and brominated (bromobutyl) were an axtension of butyl rubber developed in the 1950’s and 60’s. Compared to butyl rubber they have higher curing rates and can be co-vulcanised with other rubbers.

It has a structure similar to polyethylene, except that each second carbon atom in the polymer chain is bonded to two methyl (CH_3) groups. It is derived from the monomer isobutylene thus (Figure 1):

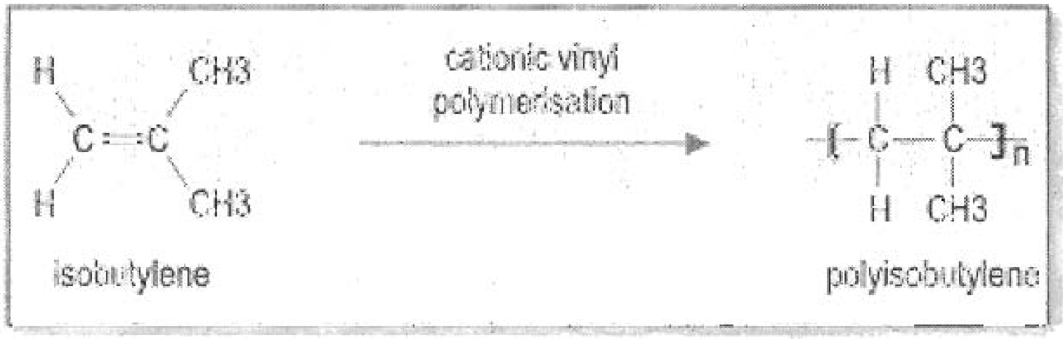

Figure 1. Structure of isobutylene and polyisobutylene or butyl rubber.

The polymer is formed by a process called cationic vinyl polymerisation and is highly exothermic. It involved the use of an initiator or cation, which attracts a pair of electrons from the carbon-carbon double bond, thus forming a single bond with the initiator. One of the carbons, previously double bonded is now positively charged and will react with another monomer, similarly to the initiator. The process is repeated until the polymer is formed.

The polymerization reaction is usually carried out at a temperature in the range - 100 C to control the reaction rate. At higher temperatures, the reaction proceeds too fast to control.

Key Properties of butyl rubber include:

- ***Air tight and gas impermeable, (a unique property of butyl rubbers)***
- ***Flexibility***
- ***Good weathering resistance***
- ***Resistant to ozone***
- *Good vibration damper*
- *Biocompatible*

Typical applications include:

- *Liners for tubeless tyres*
- *Inner tubes*
- *Inner tubes for footballs, basketballs etc.*
- *Stoppers for medicine bottles and pharmaceuticals*
- ***In sealants and adhesives***
- *O-rings*
- *Joint replacements (biomedical)*
- *Chewing gum*
- *Tank and pond liners*
- *Speaker surrounds*

All of the bolded items shown above for butyl rubber indicate why this material would be very useful in window sealing and roofing applications. Because butyl rubber is a synthetic rubber, it would tend to be more expensive than asphalt. However, it’s ability to last longer and remain flexible would be a benefit that could easily offset its added cost.

Experimental

The window/roofing flashing tapes that we evaluated were grouped according to the following categories:

Backings:

- Polyolefin film/sheet (PO)
- Foil/Foil Laminate (F/FL)

Adhesives:

- Rubberized Asphalt (RA)
- Butyl (B)

Substrates used included commonly available building materials such as:

- OSB (oriented strand board)
- Building felt
- Housewrap
- Brick

Testing methods included:

- Visual and qualitative inspection
- ASTM D903-93 for adhesion peel testing
- Thickness, ASTM D1000
- UV exposure using an Atlas Ci5000 Xenon Weatherometer; ASTM G-26
    - 2 segment
    - Light cycle 102 minutes
    - Light/spray cycle 18 minutes
    - 0.37 kjoules
    - Irradiance = 0.35 W/m2
    - Black Panel Temp = 63C
    - Chamber Temp = 42C
    - Relative Humidity = 50%
    - Specimen Spray – on

- Long term Heat aged exposure using ASTM D573. circulating air ovens
- Shear Resistance, PSTC-7 @ 150 F; 100gr/2in^2

Results and Discussion

Basic Physical Properties [3]

In Table 1 are shown the range of physical properties of the flashing systems tested:

Backing	**Adhesive**	**Overall Thickness range (mil; mm)**	**Adhesion to OSB (oz/in; N/cm)**	**Adhesion to Building Felt (oz/in; N/cm)**	**Adhesion to House Wrap (oz/in; N/cm)**	**Adhesion to Brick (oz/in; N/cm)**
PO	RA	14 – 49; 0.35 – 1.24	35 – 280; 3.9 – 31	60-255; 6.6 – 28	30-310;3.3 – 34.1	52 – 225; 5.7 – 24.8
PO	B	20 – 35; 0.5 – 0.9	125; 13.8	112; 12.3	275; 30.3	220; 24.2
F/FL	RA	45; 1.13	48; 5.3	45; 5.0	25; 2.8	70; 7.7
F/FL	B	20 – 35; 0.5 – 0.9	175; 19.3	175; 19.3	310; 34.1	245; 27

Table 1. Physical Properties of Typical Flashing Systems

The overall thickness does not include release liner. The data above (Table 1) showed that the butyl based products had consistently high adhesion to a wide variety of building substrates. The foil/butyl was consistently higher than a leading foil/asphalt type. The wide range of adhesion seen in some of the asphalt products may be the result of formulation differences or possibly a consequence of the variability of asphalt itself as a raw material in some of these adhesives.

Where we really begin to observe differentiation between asphalt and butyl PSA is in the performance testing we did using long term heat aging (LTHA) and UV/weathering exposure. For the following study we used the following flashing types:

- PO/B – two; a 20 and 35 mil (0.5 and 0.9 mm)
- F/FL/B – two; a 20 and 35 mil (0.5 and 0.9 mm)
- PO/A – seven; a 14, 23, 24, 27, 42, 46, and 49 mil (0.35, 0.58, 0.6, 0.68, 1.05, 1.15, and 1.23mm)
- F/FL/A – one; a 45 mil (1.13 mm)

UV and Weathering Exposure [3]

Backing	Adhesive	1 week Weatherometer	3 week Weatherometer	5 week Weatherometer
PO	RA	3/7 showing questionable functionality, but can still measure adh to plywood	2/7 no longer functional. 1/7 questionable functionality. Rest still functional.	4/7 no longer functional. 1/7 questionable. 2/7 still functional.
PO	B	2/2 – No change Adh to plywood = 266 oz/in (29.3 N/cm)	2/2 No change Adh to plywood = 270 oz/in (29.7 N/cm)	2/2 – No change Adh to plywood = 186 oz/in (20.5 N/cm)
F/FL	RA	1/1 – No change Adh to plywood = 105 oz/in (11.6 N/cm)	1/1 – No change Adh to plywood = 254 oz/in (27.9 N/cm)	1/1/ - 100% delamination from backing Adh to plywood = 109 oz/in (12 N/cm)
F/FL	B	2/2 – No change Adh to plywood = 148 oz/in (16.3 N/cm)	2/2 – No change Adh to plywood = 335 oz/in (36.9 N/cm)	2/2 – No change Adh to plywood = 362 oz/in (39.8 N/cm)

Table 2. UV and Weathering Exposure of Typical Flashing Systems

The results shown in Table 2 indicated that many asphalt systems showed signs of failure whereas the butyl systems did not. In general, the barrier characteristics of the foil served to protect the asphalt adhesive and this was once again evident in our long term heat aging study below. The length of exposure time in our Xenon weatherometer correlates as follows: one month of accelerated exposure is roughly equivalent to six months of real time in southern Florida.

Long Term Heat Aging (LTHA) [3]

Flashing tape samples were aged at 200 and 200F for up to 20 days. Table 3 below is a summary of our findings:

Backing	**Adhesive**	**24 hr @ 250F**	**5 day @ 200F**	**20 day @ 200F**
PO	RA	7/7 no longer functional	4/7 no longer functional	4/7 no longer functional; 1/7 questionable.
PO	B	2/2 functional	2/2 functional	2/2 functional; up to 206 oz/in adh. to plywood.
F/FL	RA	1/1 functional	1/1 functional	1/1 functional; 155 oz/in (17.1 N/cm) adh. to plywood.
F/FL	B	2/2 functional	2/2 functional	2/2 functional; up to 377 oz/in adh. to plywood.

Table 3. LTHA Aging Exposure of Typical Flashing Systems

The foil tapes seemed to be most resistant to failure due to oxidative degradation and weathering. Most likely the foil provides an effective barrier to both. Product failure with PO backings was more likely with asphalt adhesive. No failures were observed with the PO/butyl combination however.

Shear Resistance [3]

This test determined hours to failure (the tape specimen falling off of a stainless steel panel) under the temperature and load described above. Table 4 shows that the flashing systems using butyl PSA were far superior in shear resistance compared to the rubberized asphalt alternatives.

Backing	Adhesive	Hours to failure
PO	RA	1.4 – 16 hr
PO	B	48+ hr
F/FL	RA	4.3 hr
F/FL	B	48 + hr

Conclusions

From this limited and preliminary study we have been able to conclude that Butyl based PSA for flashing applications has the following advantages over Rubberized asphalt PSA:

- High and consistent adhesions due to the fact that the butyl is made under more controlled conditions than ashphalt. Butyl PSA adhere very well to typical building substrates. Our experience has also shown that these adhesives also adhere well to textured surfaces, and under cold and wet conditions.

- Butyl PSA are not as susceptible to degradation caused by UV and the combination of UV and moisture.

- Butyl PSA have better long term heat or oxidation resistance.

- Butyl PSA had superior shear resistance.

Although Butyl PSA may be more expensive in $/lb than rubberized asphalt, the added cost may be offset by savings realized by having to make less frequent repair or replacement. This analysis may be done in greater detail in subsequent publications.

References

[1] Chemical & Engineering News; Copyright @ 1999 American Chemical Society; http://pubs.acs.org/cen/whatstuff/7747scit6.html
[2] http://www.azom.com/details.asp?ArticleID=1549
[3] S. Carlisle Tyco Adhesives lab notebook references: KL1398; KL1415

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Appendix

In terms of the relationship of the LTHA accelerated aging to real time, correlations have been developed to predict actual lifetime versus the accelerated exposure. These correlations were developed for other tapes that are exposed to heat such as those used in HVAC and pipeline coatings.

For example,

In northern latitudes, typical exposure might be described as: 150F (65C) for 7 mon/yr @ 4 hr/day x 30 day/mon x 0.7 (if 70% sunny days) = 588 hr / yr.

In 25 years, this would translate to 14700hr. Our correlation has determined that for every 10C rise, equivalent aging is reduced by one half, so the equivalents would be as follows:

75C = 7350 hr
85C = 3675 hr
95C (about 200F) = 1838 hr
120C (about 250F) = 345 hr

So if our exposures in accelerated aging were the following, the equivalent real time in **northern latitudes** would be:

95C (about 200F) for 5 days (120 hr) – about 1.6 years (example: 120hr/(1838 hr/25 year)
95C (about 200F) for 20 days (480 hr) – about 6.5 years
120C (about 250F) for 24 hrs – about 1.7 years

In southern latitudes, typical exposure might be described as: 170F (75C) for 8 months/year @ 6 hr/day 70% sunny days @ 30 days/month = 1008 hr/year

Or, 1008 hr/year x 25year = 25,200 hr. If we apply the same correlation as above, then:

85 C = 12600hr
95C = (about 200F) = 6300 hr
120C (about 250F) = 1180 hr

So if our exposures in accelerated aging were the following, the equivalent real time in **southern latitudes** would be:

95C (about 200F) for 5 days (120 hr) – about 0.5 years (example: 120hr/(6300 hr/25 year))
95C (about 200F) for 20 days (480 hr) – about 1.9 years
120C (about 250F) for 24 hrs – about 0.5 years