

Butyl Based Flashing Tapes for Low Application Temperatures

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Abstract

Pressure sensitive adhesive tapes are common in the building and construction industry. One application is in window flashing and roof tapes. There has been a push for lower application temperatures for these tapes to extend the building season. To achieve this, the overall glass transition temperature, T_g , and modulus of the adhesive must be lowered so that it can wet out and stick to a variety of building materials at the desired temperature. Flashing tapes meet the American Architectural Manufacturers Association's AAMA 711 standard. Certification requires testing adhesion to oriented strand board (OSB), plywood, vinyl, and aluminum; the most difficult portion is the 24 hour dwell, 90° peel testing on conditioned panels of OSB at the desired lowest application temperature. For butyl based adhesives, possible ways to lower application temperature to OSB include increased oil content, different types of oil, lower T_g tackifiers, and alternate rubber. Rheology was used to check modulus and T_g during the screening process.

Flashing Windows with Pressure Sensitive Tapes

Flashing tapes are used to seal a window or door against moisture intrusion. Before getting into the specifics of the requirements these tapes must meet, the basics of window and door installation must be understood. The general practice is to first apply house wrap to the exterior wall of the building. The top of the window or door opening is cut directly across then down the center of the window opening but not all the way to the bottom [1]. The house wrap is then cut diagonally down to each of the corner, creating a triangle shaped flap on the bottom (Figure 1). The flaps are then wrapped around the window opening and tacked down. Across the top, the house wrap is cut diagonally from each corner away from the window and the flap is taped out of the way.

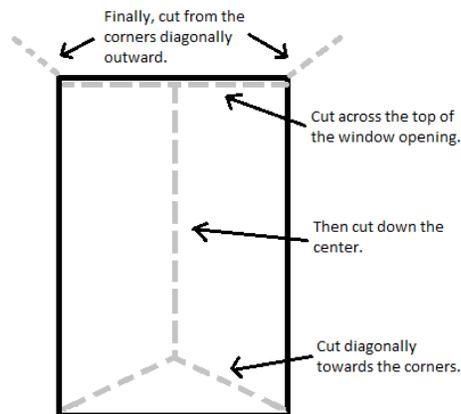


Figure 1. Before installing windows, the house wrap over the window opening must be cut as shown.

Either a sill pan or a piece of flashing is placed along the sill (Figure 2). The sill pan or stretch flashing will extend up the side of the window opening a few inches. The window is then installed as specified by the window manufacturer. Next, a piece of flashing tape is applied to each of the sides of the window, overlapping both the flange and the house wrap. This creates a seal between the house wrap and the window. Another piece of flashing tape is then used across the top. The top flap is then brought down over the flashing tape and the cuts are sealed with house wrap seaming tape. The siding, brick or trim are then installed over the flashing tape and house wrap. A properly installed window is meant to last several years. The flashing tape must be stable and maintain the water-tight seal for the life of the window, siding or brick.

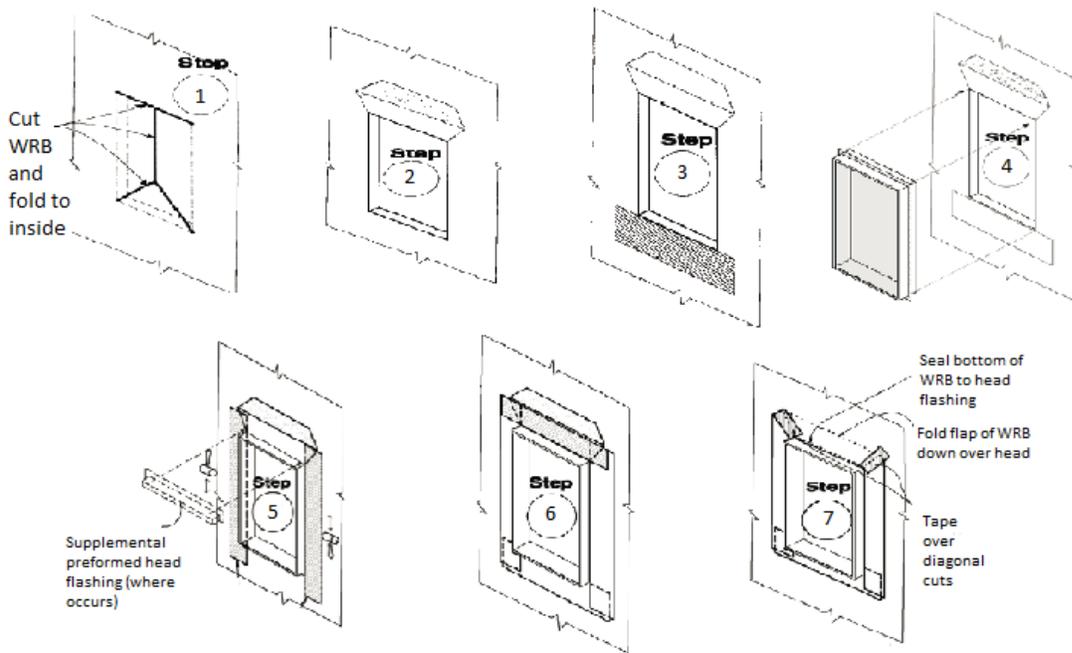


Figure 2. A step by step view of flashing a window.

Industry Standards and Certifications

The industry standard for flashing tapes is set forth by the American Architectural Manufacturers Association. The current standard is AAMA 711-13 but many tape manufacturers report tests to older standards, usually 711-07 and 711-05 [2, 3, 4]. Tapes are usually tested to the most current standard when they are developed and due to the very small changes from one revision to another, are not updated. Most but not all tapes strive to meet the standard. The adhesive used in the flashing tape can be acrylic, butyl or rubberized asphalt [5]. All three adhesive types are tested to the same standard.

Meeting the standard requires a long list of testing. The most difficult portions of the certification center around adhesion to a variety of substrates like oriented strand board (OSB),

plywood, vinyl, and aluminum not only at room temperature but at lower temperatures. Luckily, the tape manufacturer determines the lower application temperature of the flashing tape. The tape must exceed 1.5 lbs/in (24 oz/in) for 24 hour dwell, 90° peel testing on panels that have been conditioned at the specified temperature. The tapes must also meet an upper use requirement of 1 week at 80°C for level 3 (65°C for Level 2, and 50°C for Level 1) on aluminum panels without slipping, falling off, or changing in general appearance. Such high temperature testing would give some indication as to how a tape would behave during construction in the midst of a summer heat wave. There is also a nail sealability requirement that can prove difficult. The tape must seal around a nail that is then subjected to water and temperature fluctuations without leaking. Things like siding or window trim may be nailed to the wall through the flashing tape and the tape's ability to seal against water intrusion is critical.

In the past few years, there has been a strong industry trend towards lower and lower application temperatures in flashing tapes. A tape that can be applied successfully to the desired substrates when the outside temperature is freezing or below can dramatically extend the building season for contractors. These claimed lower application temperatures can range anywhere from 30°F to -20°F. At lower temperatures, a primer is often suggested to increase the bonding capability of the adhesive. There are several ways to lower the application temperature of the tape but it must be done with consideration for the upper temperature requirements. The glass transition temperature (T_g) and modulus (G^*), are indicators of how soft the adhesive is at a given temperature. A softer adhesive is better able to stick at lower temperatures so lowering T_g and G^* of an adhesive will lower the application temperature of the adhesive.

Rheology of Adhesives – A Way to Screen Flashing Tape Adhesives

Rheology is an excellent screening tool for developing new adhesive formulations. The adhesive is placed between two parallel disks in a parallel plate geometry [6]. One of the plates remains stationary while the other rotates. Adhesives are most commonly tested using oscillatory shear. For the purposes of these experiments, a temperature sweep where the material is heated at a constant rate and tested at a constant frequency to create a modulus curve as a function of temperature. Rheological data discussed in this paper was all collected using a frequency of 1 rad/s and a heating rate of 4°C/min.

The flow behavior of rubber based adhesives like the ones discussed here have both a viscous and an elastic component. The oscillatory experiment gives the complex modulus, G^* , a measure for the softness or hardness, and the loss tangent, $\tan \delta$, a parameter quantifying the elasticity or viscous behavior. The viscoelastic properties can also be described by the storage modulus, G' , and the loss modulus, G'' , which can be calculated from G^* and $\tan \delta$. When the $\tan \delta$ curve is plotted as function of temperature, the glass transition temperature, T_g can be determined. The $\tan \delta$ curve goes through a maximum at T_g , making the value simple to determine. Below T_g , the adhesive is very brittle and the modulus is very high. At T_g , the adhesive begins to soften.

The modulus curve has often been used to determine how an adhesive might perform under specific conditions. Frequently referenced is the Dahlquist criterion [7]. The Dahlquist criterion is often used to determine the operating temperature of an adhesive; the modulus should be in the range of 50 to 300 kPa to have enough shear resistance but also be soft enough to wet out a substrate. For these

experiments, the focus will be on the lower application temperature, known as T_D , where the modulus drops below 300 kPa and is considered soft enough to wet out a substrate.

Oriented strand board (OSB) is a very rough and difficult to stick to substrate. As already mentioned, it is the most difficult substrate of the AAMA 711 required substrates to stick to. It should be noted that 300kPa is not soft enough to wet out OSB successfully, but using a standard measurement like T_D is still quite useful as a guide when attempting to reformulate an adhesive to change the lower application temperature for adhesion to OSB.

Modifying the T_g of Rubber Based Adhesives

Rubber based adhesives are made up of a limited number of ingredients. They generally consist of oils, tackifiers, fillers and rubber. The size and direction of the impact of changing any of these components varies and is shown with Figure 3. As previously mentioned, flashing tapes are meant to last several years without failing making the use of unsaturated rubbers such as natural rubber unsuitable. The choice for the rubber portion of the adhesive is therefore limited to only saturated rubbers. The rubber portion could be butyl rubbers, styrene butadiene copolymers, and ethylene-propylene rubbers. Changing the type of rubber the adhesive base is made of can change the T_g of the resulting adhesive but for simplicity, the focus will be on modifying the T_g of butyl based rubber adhesives.

Fillers are usually used to decrease the overall cost of the adhesive. These are the cheapest components of the adhesive. Changing the filler or filler level can have an impact on T_g , but changing the filler is not often the most economical choice.

Tackifiers are usually high T_g hydrocarbon resins or rosin esters. If the goal is to lower the application temperature, increasing the tackifier will move the T_g in the wrong direction or not move the T_g at all. There are liquid tackifiers with a low T_g that can be used but again, for simplicity, the focus will be on increasing and decreasing the oil content to modify the T_g .

Oils will be the focus of the experiments below. There are a few options in terms of what oils can do to modify T_g of an adhesive. There are many different grades of oil on the market, some with low molecular weights and some with very high molecular weights.

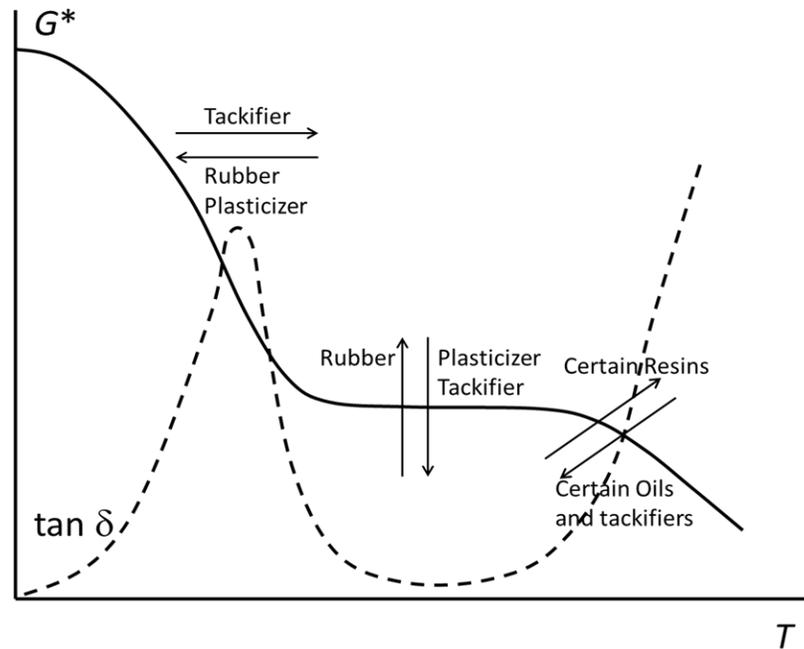


Figure 3. The various components of a rubber based adhesive will shift the modulus and T_g in predictable ways.[6]

Two sample base formulations were created using butyl rubber, filler, tackifier, and oil. Sample A used only these ingredients and the amount of oil a low molecular weight was varied in order to lower T_g and T_D . The adhesion to OSB was then tested at the lower target temperatures. Sample B used the same ingredients but this time the oil was changed from a higher molecular weight oil to a lower molecular weight oil and the goal was to match the T_g , T_D and application temperature as the original formulation.

Experiment A – Lowering the Lower Application Temperature by Adding Oil

Rheology testing was performed on the Sample A base formula to determine T_g and T_D . T_g of the formula was -21.6°C and the T_D was -9°C (see Figure 4). The sample was then calendered at 15 mils adhesive thickness and laminated to a flexible backing. The sample's adhesion to OSB was then tested at 40°F . The sample was found to have 24 oz/in peel force, which is enough to pass the AAMA 711 peel standard. A target of 30°F application temperature was selected.

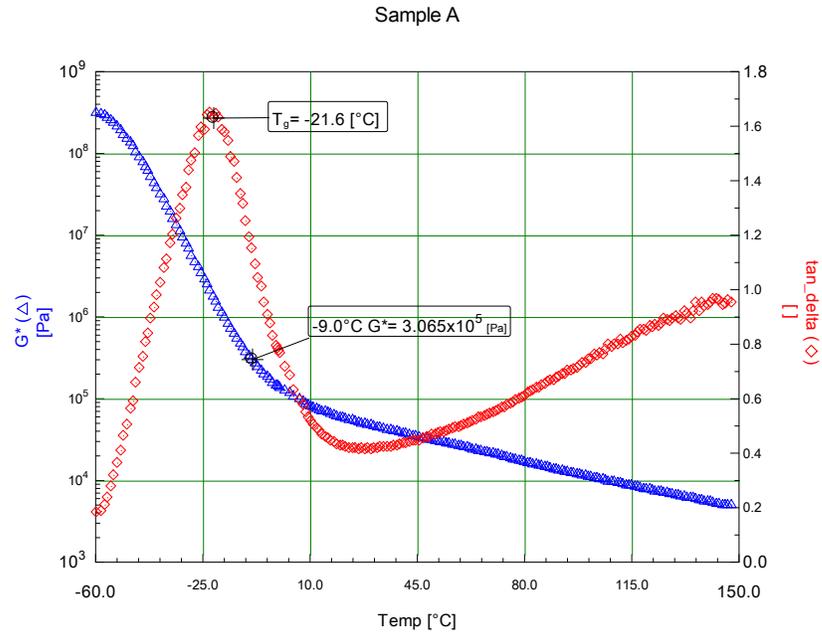


Figure 4. T_g and T_D were determined based on the rheology data.

The base formula was then modified with three different levels of oil. The correlation between the level of additional oil and the shift in T_g is also shown in the rheology curves below (Figures 5 and 6) below. The T_g of these samples were then measured and are shown in Table 1 below.

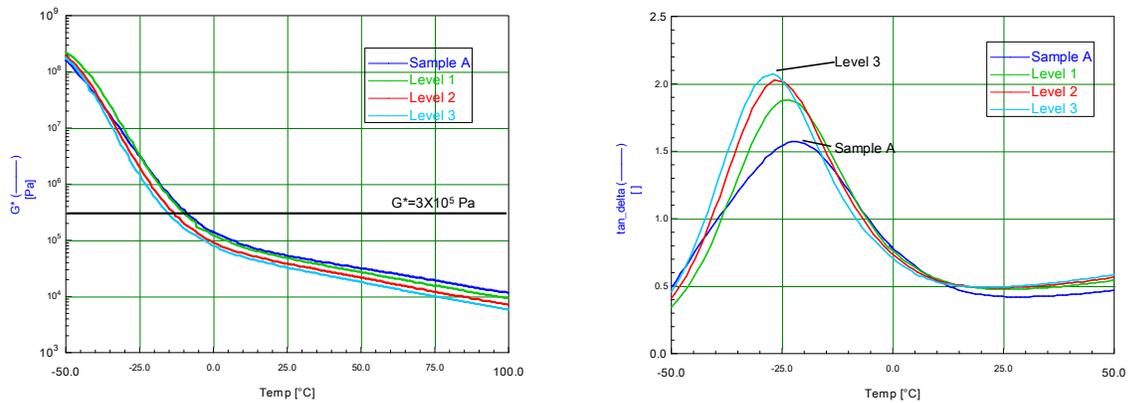


Figure 5 (left). Increasing the oil content shifts the G^* curve to the right. The line indicates where $G^*=3 \times 10^5$ Pa. T_D is where G^* intersects this line.

Figure 6 (right). The T_g values were determined from the $\tan \delta$ curve.

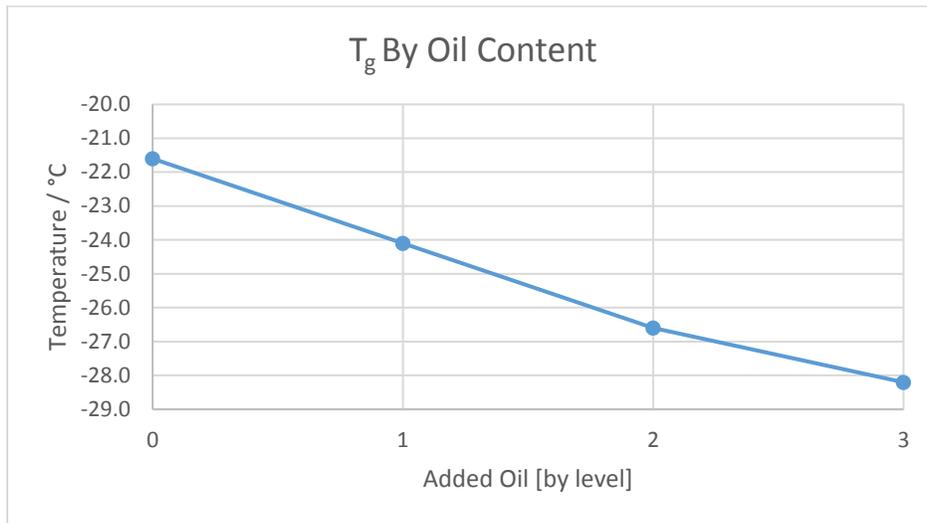


Figure 7. The change in T_g and the increase in oil content show a linear correlation.

It was found that Level 2 should have enough of a shift in T_g of the adhesive by the required 10°F. Samples A (0), 2 and 3 were then calendered at 15 mils and laminated to a flexible backing for peel testing at 30°F. The peel results are shown in Table 1 and Figure 8.

Sample	T_g (°C)	T_D (°C) (approx.)	Peel Adhesion from OSB at 30°F (oz/in)
Sample A (Level 0)	-21.6	-9	16
Level 1	-24.1	-10	Not Tested
Level 2	-26.6	-13	32
Level 3	-28.2	-15	44

Table 1. The range in oil content, the resulting T_g , T_D and peel from OSB are shown. Peels were done according to the AAMA 711 specification, 90° peel angle, 24 hours dwell at 30°F.

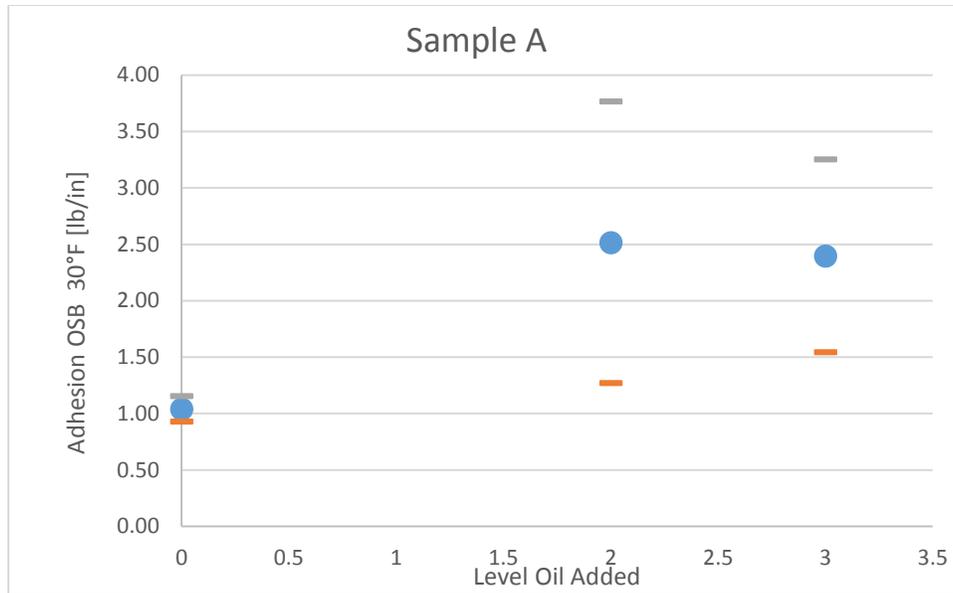


Figure 8. The increase in oil increased the adhesive’s ability to wet out and bond to OSB at 15 mils adhesive thickness.

The sample was found to have 36 oz/in (2 lbs/in) peel force, showing that the additional oil successfully lowered the application temperature. While slightly less oil might yield a formula that would also pass the AAMA 711 peel requirement on OSB, peel values from OSB have a high degree of variability as demonstrated by the wide error bars. The Level 2 sample should have peel values that are high enough to compensate for the variability of the substrate and maintain an average safely over the minimum.

Experiment B – Comparing the Effects of Higher and Lower Viscosity Oils on T_g

Sample B originally had a T_g of -44.9°C and T_D of -29.5°C . Through peel testing, the lowest application temperature was found to be 10°F . It is possible to make a rubber based adhesive too soft. Softer adhesives have a tendency to bind to release liners even at ambient temperatures. Tapes made with very soft adhesives, particularly adhesives softened with oil, tend to exhibit significant edge ooze. The upper temperature requirements of AAMA 711 also discourage making an adhesive too soft using oil. For this experiment, the goal was to switch from a high molecular weight oil to a low molecular weight oil and maintain the performance. An adhesive much softer than the original formula would make a very poor tape at ambient and higher temperatures.

It was hypothesized that the lower molecular weight oil would decrease the T_g when used in the same quantities so the oil content was decreased to compensate. Three formulations were made based on Sample B’s original formulation. The oil was decreased by a consistent amount in each sample with Sample B-1 as a one to one switch from high molecular weight to low molecular weight oil. Table 2 below shows the T_g and T_D data for each formula as well as the peel force from OSB at 10°F data. The T_g

values are very close together, so the T_D values were also examined in order to determine which formula may give the closest match to the original Sample B formula (Table 2).

Sample	Level of Oil	T_g (°C)	T_D (°C) (approx)	Peel adhesion from OSB at RT (oz/in)	Peel adhesion from OSB at 10°F (oz/in)
B	Level 0	-44.9	-30.0	99	29
B-1	Level 0	-43.7	-32.0	74	52
B-2	Level 1	-42.7	-30.8	67	35
B-3	Level 2	-44.8	-29.8	60	27

Table 2. The original formula and B-1 have the same amount of oil but B has a high molecular weight oil while B-1, B-2 and B-3 all use the lower molecular weight oil. Peels were performed according to AAMA 711, 90° peel angle, 24 hours dwell at 10°F and room temperature.

The rheological results show that the best match is sample B-3. All three samples were tested for peel performance on OSB at 10°F. All three samples passed but as predicted, Sample B-3 gave results that were the closest to Sample B. Sample B-1 was extremely soft at room temperature and was determined to be too soft to be a good flashing tape. If there were no high temperature performance requirements, Sample B-1 might make an excellent cold temperature flashing tape. Sample B-2 also gave excellent results. It has better peel properties at 10°F compared to the original formula and likely maintains its high temperature performance. Sample B-3 is the closest match to Sample B but has a slightly lower T_g , slightly lower T_D , and slightly lower peel force at the target temperature. The differences are small though and likely not significant. Again, as with Experiment A, Sample B-2 would be a safer choice to maintain a peel average well above the minimum requirement.

Conclusions

Pressure sensitive tapes are widely used in the building and construction industry, particularly as flashing and roofing tapes. The recent trend of lower application temperatures has helped to extend the building season. In order for the adhesive to wet out the substrates at lower temperatures, the glass transition temperature (T_g) and modulus (G^*) must also be lowered. The American Architectural Manufacturers Association sets the industry standard for flashing tapes. The most difficult of the substrates that the standard requires adhesion to is oriented strand board (OSB), 90° peels from conditioned panels after 24 hours dwell. Modifying a rubber based adhesive can mean changing the oil content, changing the type of oil used, changing the rubber, switching to a different tackifier or using an alternate rubber. The two experiments discussed used rheology to determine the T_g and T_D alongside traditional adhesive testing to the AAMA 711 standard on OSB to screen the adhesive formulations.

References

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