Trackless Tack Coat Materials – A Laboratory Evaluation For Performance Acceptance

Trenton M. Clark, P.E.
Asphalt Program Manager
Virginia Department of Transportation Materials Division
1401 East Broad Street
Richmond, VA 23219
Telephone: (540) 860-2495
Fax: (804) 328-3130
Trenton.Clark@vdot.virginia.gov

Todd M. Rorrer
Assistant Asphalt Program Manager
Virginia Department of Transportation Materials Division
1401 East Broad Street
Richmond, VA 23219
Telephone: (804) 328-3028
Fax: (804) 328-3130
Todd.Rorrer@vdot.virginia.gov

Kevin K. McGhee, P.E.
Associate Principle Research Scientist
Virginia Transportation Research Council
530 Edgemont Road
Charlottesville, VA 22903
Telephone: (434) 293-1956
Fax: (434) 293-1990
Kevin.McGhee@vdot.virginia.gov

Corresponding Author: Trenton Clark

Word Count: 3827 words + 7 tables + 5 figures = 6,827

ABSTRACT

During the design of a pavement structure, the engineer assumes the loads applied by traffic will be distributed in such a manner that minimizes pavement distress. For flexible pavements, the impacts of the loadings are reduced by using high quality materials in the asphalt bound layers at a designed thickness in order to minimize fatigue cracking in the bottom of the asphalt concrete section and rutting in the top of the subgrade. However, when the engineer makes this assumption, they design for a "no slip" (i.e., bonding) condition between asphalt concrete layers resulting in a monolithic structure. Unfortunately, the "no slip" condition is not always provided during construction.

While the importance of the bond is known during pavement design, the use of tack coat materials in the field is often omitted or not applied at the specified application rate. The predominant reason for not following the specifications is the tracking of tack onto adjacent pavements. Tracking results in build up at intersections and covering of permanent pavement markings. This leads to additional costs to the contractor as well as safety concerns. Unfortunately, the cost to the pavement's owner for not achieving good bond is much higher due to premature functional and structural failures.

For certain applications, VDOT will specify the use of a tack coat material that meets its special provision for non-tracking tack. This special provision was developed based on experience with one material. Since developed, additional suppliers have provided materials for consideration and acceptance as trackless tack. This paper will outline the approach VDOT used to assess each material and the testing results. This paper will provide conclusions as well as recommendations for future research.

INTRODUCTION

Bonding between asphalt concrete layers is provided by two methods – chemical bond and mechanical bond. For most new construction and straight overlay projects, a chemical bond is achieved through the use of a tack coat material. This material is either a neat or modified liquid asphalt, or an asphalt emulsion (combination of water and liquid asphalt). The tack coat provides the glue between two layers in order to allow for the transfer of stresses and strains from one lift/layer to the underlying layer. When milling is performed on an asphalt surface prior to overlay, the milling teeth creates grooves and ridges. As the new asphalt concrete is placed and compacted on the milled surface, aggregate in the new asphalt concrete is locked into the grooves and ridges creating a mechanical bond. This mechanical bond, in conjunction with the chemical bond resulting from the tack coat, provides a "no slip" interface. Whether a chemical or mechanical bond is formed, the bond is necessary to meet the structural design life of the pavement.

While the importance of the bond is known during pavement design, the use of tack coat materials in the field is often omitted or not applied at the specified application rate. The predominant reason for not following the specifications is the tracking of tack onto adjacent pavements. Tracking results in build up at intersections and covering of permanent pavement markings. This leads to additional costs to the contractor as well as safety concerns. Unfortunately, the cost to the pavement's owner is much higher due to premature functional and structural failures.

Background

In 2005, VDOT was approached by a tack coat supplier with a new material – "trackless" tack. This material had been used in other states in the Southeast and the supplier wanted to introduce the material in Virginia. At their cost, they proposed a series of demonstration projects around the commonwealth. VDOT and the supplier identified paving contractors and project sites to try this new trackless tack. Essentially, according to the supplier this new material used a very hard performance graded binder and had a positive charge. Once applied to the surface through a conventional distributor, the emulsified tack coat broke in a matter of minutes. After a series of projects and testing by VDOT, a special provision for Non-Tracking Tack Coat was developed for use on projects (*1*). The initial special provision stated the tack coat had to develop a minimum tensile strength of 40 psi. The evidence of tracking would be determined through the use of a colorimeter; a device used to determine the reflectance of pavement marking. Finally, the special provision provided trackless tack coat material properties applicable to the initial material. While this special provision was available for statewide use, only isolated regions of the state incorporated it into the 2006 maintenance asphalt resurfacing schedules.

Figure 1 Trackless Tack (notice no tack pick-up on tires)

With the emergence of a new market through the special provision, other tack coat suppliers in Virginia began developing their version of "trackless" tack. The materials and methods they used were different from that of the initial supplier. As such, while they may have produced what they deemed a "trackless" tack, the new products could not meet the more fundamental material requirements of the original special provision. This left the Department in an interesting position – force all suppliers to meet a special provision based on a single product or evaluate each new material independently of the special provision.

PROBLEM STATEMENT

Since 2005, VDOT has had a single special provision for "trackless" tack. This special provision was based on initial success of one product. The product was able to eliminate tracking as well as provide an acceptable bond between pavement layers which meets the needs of the pavement design engineer.

With the continued use of the special provision in Virginia, more tack coat suppliers entered the market with their material. These products could not meet the special provision criteria; thus, the suppliers would request a waiver or modification of the special provision in lieu of a field acceptance. This led to new materials being used, but rendered the special provision worthless. To make the special provision useful, it had to meet three criteria:

1. Address all material properties to cover all possible "trackless" tack coat formulations,
2. Define tracking (and how it would be measured), and
3. Set minimum bond strength performance criteria.

After careful consideration, it was decided to address criteria 2 and 3 in a special provision. The definition of tracking is very loose and not well defined. Additionally, the bond strength for conventional tack coat materials used in Virginia (CRS-1 and CRS-2) and the initial "trackless" tack coat material is known; but with minimal experience and performance information with these formulations, the actual bond strengths generated are not known. Criteria 1 would be set by the supplier for monitor testing by the Department.

PURPOSE AND SCOPE

The purpose of this study was to develop a laboratory evaluation and a field validation process for tack coat materials; primarily "trackless" tack. At the completion of this study, the following products will be developed for implementation:

1. Revised special provision for use in Virginia,
2. An approved products list for "trackless" tack,
3. A laboratory evaluation process for use by suppliers prior to submitting new materials to VDOT for approval,
4. A field validation process for use by suppliers prior to submitting new materials to VDOT for approval

This paper will detail the laboratory procedures used by VDOT's Central Office Materials Division Asphalt Section labs and the Virginia Transportation Research Council's asphalt mix and binder labs to evaluate 5 "trackless" and 2 conventional tacking materials. The paper will describe each test performed and provide the corresponding results. It must be noted that the results from the laboratory evaluation were not used to preclude any material from the field validation. Near the completion of the study, field validation results were used to assist in setting the minimum laboratory values and developing an Approved Products List for use by contractors in Virginia. The field evaluation phase of this study will be presented in a subsequent paper.

METHODS

For the laboratory evaluation process, three primary types of tests were conducted. Two of the tests were performed by the Central Office Asphalt Labs (COAL) and one was performed by the VTRC. Tests were performed on the 5 experimental products and the two control products. The tests were:

1. Characterization of the tack coat material, i.e., material properties, based on the information provided by the supplier (COAL)
2. Tracking of tack coats in a laboratory environment (COAL)
3. Bond strength of the tack coat (VTRC)

"Trackless" tack coat materials are referenced with a letter from A to E. The conventional tacks, used as the control in this study, are identified as either CRS-1 or CRS-2.

Material Properties

Located at the Central Office Materials Division, the Asphalt Section has a binder and emulsion lab. This lab is charged with performing system-wide independent assurance testing as well as project level quality assurance testing. The lab is AMRL accredited and is able to perform viscosity testing (AASHTO T 72), penetration testing (AASHTO T 49), residual asphalt cement (AASHTO T 59), and ring and ball softening pointing (AASHTO T 53) to name a few.

Based on the product's material properties provided by the supplier, VDOT performs an independent assurance review. For the materials provided, VDOT performed residue percent by distillation (AASHTO T-59), penetration (AASHTO T-49), furol viscosity (AASHTO T-72), and ring and ball softening point (AASHTO T-59). If the material is accepted by VDOT as "trackless" and is placed on the Approved Products List for Trackless Tack, then these material properties will be monitored, just like other bituminous materials (i.e., asphalt binders, emulsions and cutback materials) As long as the material meets the suppliers defined property values (minimum value, maximum value, acceptable range) and no problems are reported on projects, then no additional actions will be taken. However, if problems are reported in the field or lab results indicate the material has changed, then additional investigation will be required. The defining of the material based on the supplier's criteria was an essential step in the lab process.

Lab Tracking Tests

Several approaches were considered for determining the amount of tracking exhibited by a material. Whichever approach that was selected, it had to be perform consistently with every product. After researching various approaches, VDOT decided to use the device and a procedure similar to ASTM D711, No Pick Up Time of Traffic Paints (*2*). This approach is used to evaluate pavement marking, specifically epoxy, applied at different thicknesses.

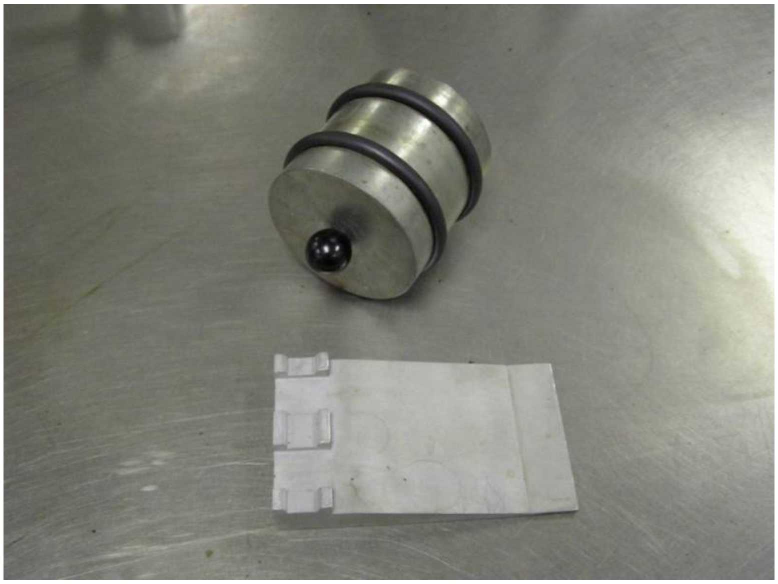

Figure 2 Tracking/Pickup Device used in ASTM D711.

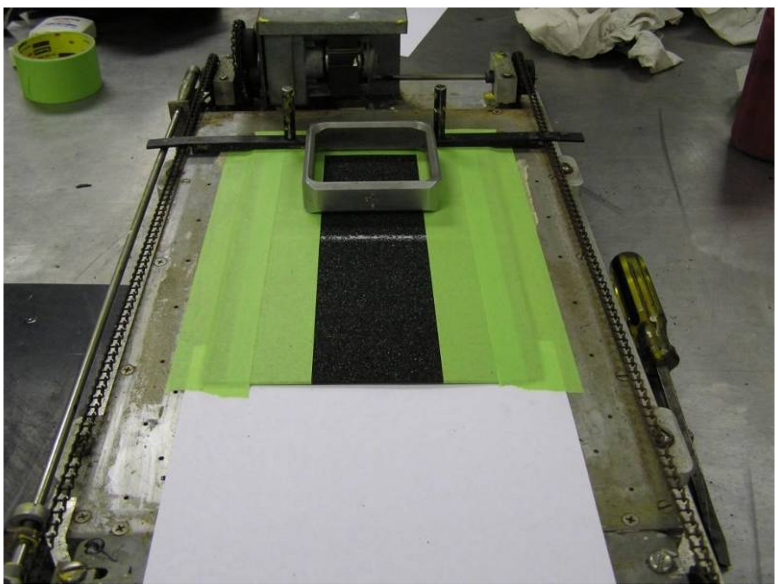

Figure 3 Draw down device for applying tack at desired rate.

Following ASTM D711, two sets of tests were initially developed. The first test was to determine the tracking characteristics of the products at various stages of cure in a laboratory environment. The second test was to determine the tracking characteristics once the water had evaporated completely from the material. Both tests were evaluated using a subjective evaluation procedure developed by VDOT and described later in the report.

Room Temperature Tracking Test

The purpose of the room temperature tracking tests was to assess the amount of time required for a material to become "trackless". Using the 0.8 mm thickness setting in ASTM D711, tack coat material was applied to a piece of roofing paper. Roofing paper was selected to replicate an asphalt surface. Then, the material was allowed to sit for predetermined periods of time. After 20 minutes, ASTM D711 was performed. The cylindrical weight was allowed to roll through the tack on the roofing paper and then across a white sheet of paper. This process was repeated every 10 minutes until 60 minutes from time of initial tack application had elapsed. All seven tacking materials were performed in this manner.

The residual application rates reported for these tests were determined from the measured mass just prior to the first pass of the tracking device. For the room temperature tests this rate may include any remaining water in the tack at that time.

Oven Dried to Constant Mass Tracking Test

The purpose of the oven dried to constant mass tracking tests was to assess the materials' tendency to track once all water had evaporated. Using the 0.8 mm thickness setting in ASTM D711, tack coat material was applied to a piece of roofing paper. Roofing paper was again selected to replicate an asphalt surface. Then, the material was placed in an oven at 95°F until a constant mass was reached. Constant mass for the purposes of this study was defined as an initial 15 minute cure time followed by two consecutive mass readings with 0.0g difference at 5 minute intervals. The cylindrical weight was allowed to roll through the tack on the roofing paper and then across a white sheet of paper. All seven tacking materials were tested in this manner.

The residual application rates reported for these tests were determined from the mass at the end of the measured constant mass check.

Lab Bond Strength Tests

The fundamental purpose of a tacking material is to provide bond strength. For the interface, the tensile and shear strengths are important. As the depth in the pavement increases, the need for tensile strength outweighs shear strength due to the minimized lateral forces from braking and other turning.

The bond strength procedures are thoroughly described in a related and earlier report (*3*). For easier reference, a summary of those procedures is provided here. The reader is encouraged to review the earlier report for the finer details relating to specimen preparation and testing.

Specimen Preparation

The strength specimens were constructed in a SUPERPAVE™ gyratory compactor using locally produced dense-graded asphalt concrete (AC). The two-inch lower layer, which represented the original surface, was prepared first and set aside to cool to room temperature. The top surface of this layer is then "aged" through sandblasting and then warmed to 50º C. The tack coat material was applied with a paint brush at the desired rate (0.075 gal/sy) and the coated specimen set aside to cure until the surface was no longer "tacky" to the touch (usually between 5 and 10 minutes for trackless tack materials, longer for conventional materials). The rate of 0.075 gal/sy is the mid-point in the specification range for tack coat application in Virginia. The lower layer, complete with a cured tack coat surface, was then placed back into the gyratory compactor and a fresh layer of AC placed and compacted on top of it. The completed specimen was then set aside to cool overnight.

Tensile Strength Testing

The first laboratory bond test focused on tensile strength of the tack coat materials. To ready the specimens for testing, circular steel plates with threaded holes in the center were affixed with epoxy to the flat top and bottom surfaces of each asphalt concrete specimen. After the epoxy was permitted to cure overnight, eye bolts were threaded into the circular plates, and the specimens were placed in a universal testing machine. The specimens were then tested at room temperature to failure at a loading rate of 1,200 lb/min. The reported tensile strength was the load at failure divided by the nominal surface area of the specimen.

Shear Strength Testing

The second bond test sought to determine the shear strength of the tack coat interface. These tests were performed using a jig designed to operate within a Marshall device for compression loading as described in ASTM D 6927, Standard Test Method for Marshall Stability and Flow of Bituminous Mixtures (*2*). Figure 4 is an image of the shear testing jig. The jig functions like a guillotine with the specimen oriented such that the layer interface is centered in a ¼-in slot between the fixed and movable components of the device. The total load on the interface is the load applied by the compression device plus the weight of the movable portion of the jig. The shear strength of an interface is the maximum total load achieved divided by the nominal surface area of the specimen.

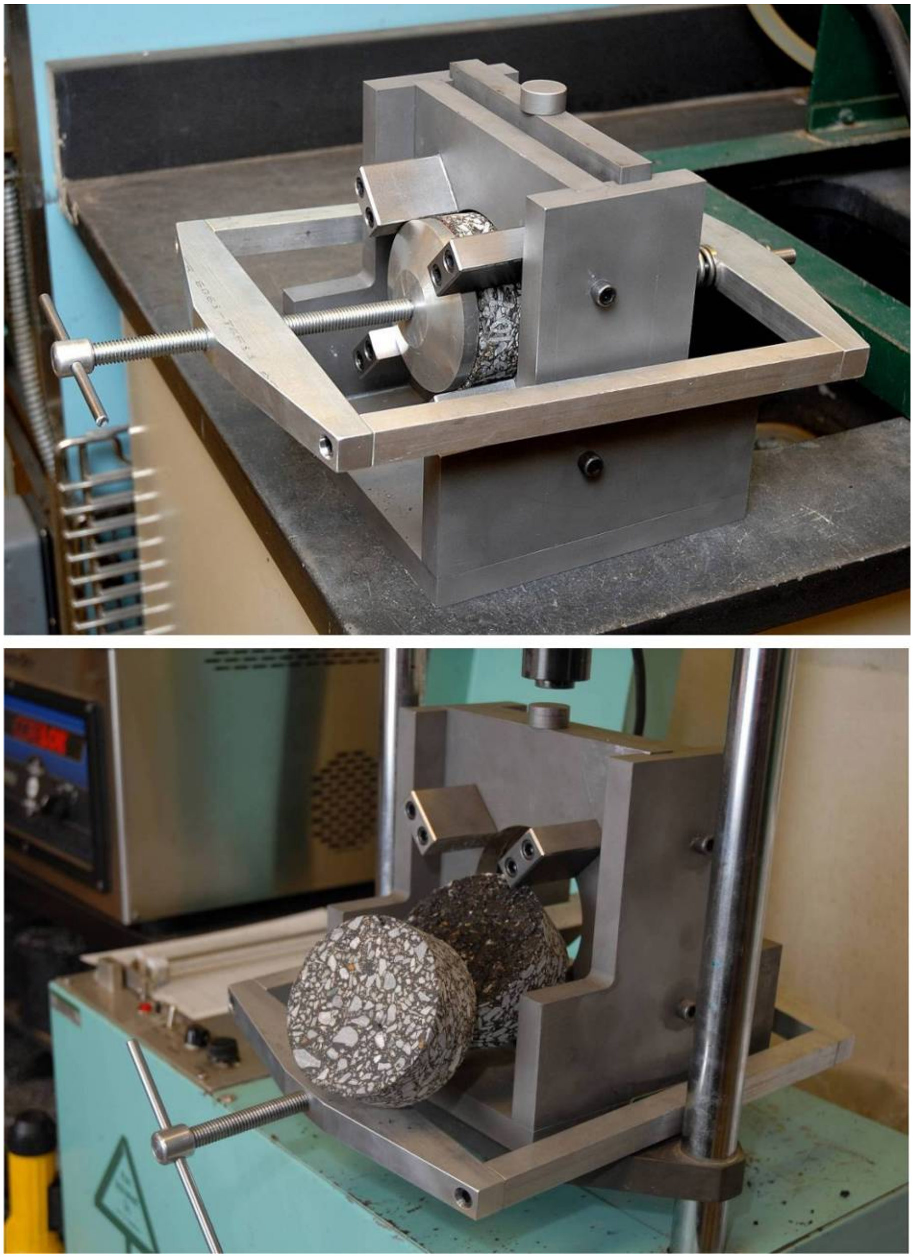

Figure 4 Shear testing device.

RESULTS

Material Properties

All materials submitted to VDOT were tested against the supplier's material specifications. These specifications would be used by VDOT in the independent assurance program to determine if the material supplied to a project was acceptable. For the five trackless tack materials submitted, all met the requirements set forth by the supplier.

Lab Tracking Tests

To evaluate the tracking, a visual rating scale was developed. A value of 10 was assigned for full pick up and tracking along the length of the drawn out sample. A value of 0 was assigned when no pick up or tracking was visible. A value of 5 meant tracking was present for either one rubber gasket for the entire length of the paper or both gaskets for approximately ½ the length of the paper. Figure 5 shows some typical results from the tracking tests. Example a) was rated as a 9 due to the partial tracking along the length of the wheel track. Example b) was given a rating of 7 as one full length of the sample tracked and there was intermittent tracking on the opposite gasket.

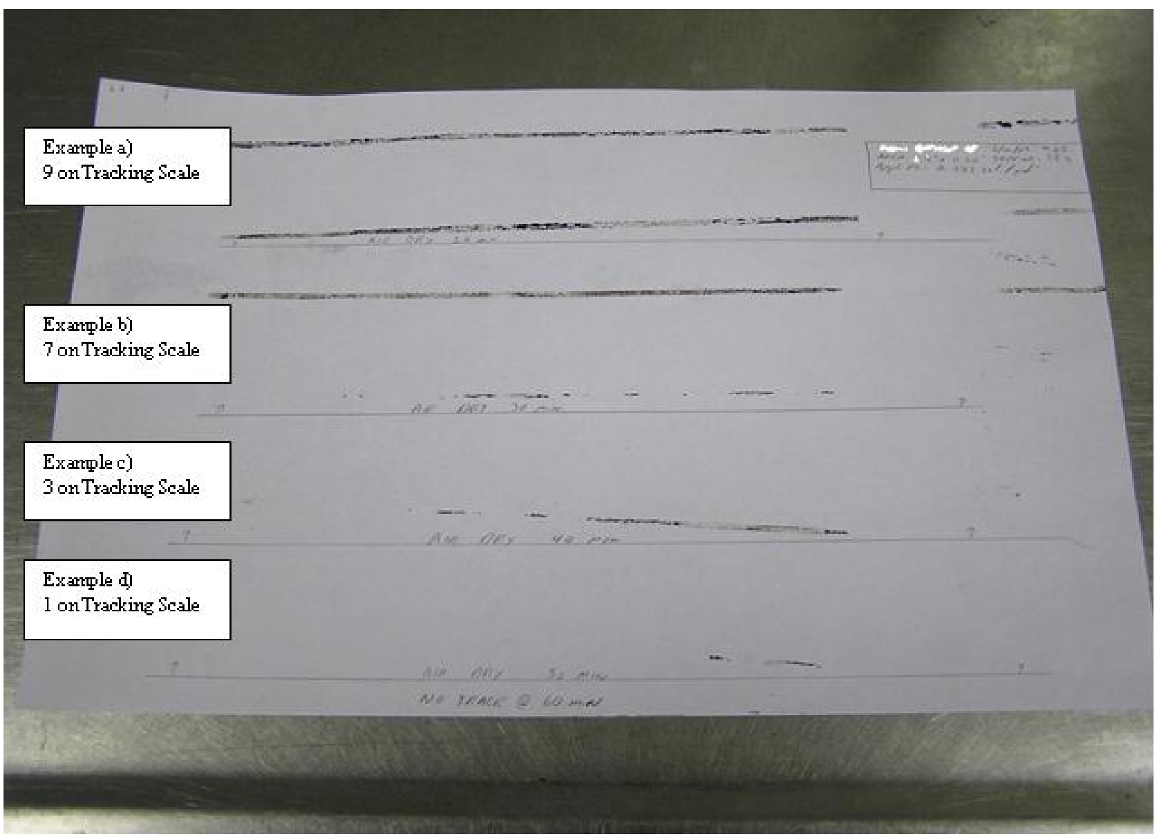

Figure 5 Tracking evaluation scale.

Room Temperature Tracking Tests

Given the subjective nature of the test, three different raters provided independent ratings of the tracking results. The rating was average for each material. The results of the testing are provided in Table 1, which identifies the material, the average residual application rate and the time since initial application.

Table 1 – Room Temperature Tracking Results (Round 1)

Material	Avg. Residual (gal/sy)	Track Rating Time		
		40 min	50 min	60 min
A	0.065	0	0	0
B	0.085	1.7	1	0
C	0.062	0	0	0
D	0.055	5.7	5	1
E	0.08	3.7	0.7	0.3
CRS – 1	0.047	7.5	6.3	5.7

Clearly, after one hour materials A, B and C showed no signs of tracking. Materials D and E had trace amounts of tack on the paper. Essentially, all trackless tack coat materials did not track in the lab, even though the average residual material varied from 0.055 to 0.085 gal/sy. Interestingly, CRS-1 had extensive tracking after one hour and the lowest residual application rate.

The first round of room temperature tracking tests was performed by passing the cylindrical device over the same tack sample for each time increment. After discussion among the project team, it was decided to perform a second round of testing. To eliminate the possibly of decreased tracking due to removal of tack during previous tests, three new samples were prepared for each material. One sample was tested at 40 minutes and one sample at 50 minutes. The same rating process was used in the second round of room temperature testing. Table 2 contains the results for all samples except material E. The manufacture did not provide new tacking material. The testing for Round 2 was moved from counter top testing to an enclosed laboratory hood to reduce temperature variability that may effect curing time. The temperature in the hood was monitored during all testing and was maintained at 74 +/- 2^{o}F

Table 2 – Room Temperature Tracking Results (Round 2)

Material	Curing Time – 74^{o}F			
	40 min		50 min	
	Residual Application Rate (gal/sy)	Track Rating (0-10)	Residual Application Rate (gal/sy)	Track Rating (0-10)
A	**0.06**	**0.3**	**0.04**	**0.2**
B	**0.11**	**6.0**	**0.10**	**5.0**
C	**0.06**	**0.3**	**0.05**	**0.3**
D	**0.08**	**5.3**	**0.07**	**2.3**

Material	Curing Time – 74°F			
	40 min		50 min	
	Residual Application Rate (gal/sy)	Track Rating (0-10)	Residual Application Rate (gal/sy)	Track Rating (0-10)
E	Second Sample not Received			
CRS-1	**0.05**	**10.0**	**0.1**	**10.0**

Oven Dried to Constant Mass Tracking Tests

The average ratings (three specimens per material) for the samples cured to a constant mass at 95°F are provided in Table 3. The majority of the samples achieved constant mass within 20 minutes and no sample spent more than 25 minutes curing.

Table 3 –Constant Mass Tracking Results

Material	Avg. Residual (gal/sy)	Average Track Rating
A	0.052	0
B	0.064	0.3
C	0.047	0
D	0.048	0.3
E	0.053	0.3
CRS – 1	0.042	8

At constant mass, materials A and C showed no signs of tracking. Materials B, D and E had trace amounts of tack on the paper on one of the three specimens and 0 on the remaining two. Overall, all materials did not track in the lab, even though the average residual material varied from 0.047 to 0.064 gal/sy. Interestingly, CRS-1 exhibited extensive tracking and the lowest residual application rate. CRS-1 is made with a soft liquid binder grade and even after curing to constant mass the material remains tacky.

Bond Strength Results

The bond test results for the non-tracking tack materials are presented in Tables 4 and 6. The results for each material represent an average and standard deviation from 6 specimens of each test type. For example, the 95 psi tensile strength reported for non-tracking material 'A' is the average of six individual test results. For comparison purposes, the average strength measurements for two CRS-1 materials and 4 CRS-2 materials are presented in Tables 5 and 7. For the conventional materials, each reported value for the CRS-1 classification represents 12 tests, and the values reported for CRS-2 represent 24 (6 tests each of 4 products).

Tensile Strength

On average the non-tracking tack materials provided an approximately 25 to 30-percent tensile strength advantage over the conventional materials in the laboratory setting.

Material C was particularly impressive, as it not only provided the highest average tensile strength, but did so with remarkable consistency – a standard deviation of roughly one-half of the next most consistent material.

Table 4 –Tensile Strength - Non-Tracking Tack Materials

Material	Tensile Strength	
	Average (psi)	Std. Dev. (psi)
A	95	13.8
B	102	7.8
C	137	3.4
D	108	7.3
E	109	9.7
Average	**110**	**8.4**

Table 5 - Tensile Strength - Conventional Tack Materials.

Material	Tensile Strength	
	Average (psi)	Std. Dev. (psi)
CRS-1	88	16.2
CRS-2	85	11.7

Shear Strength

The shear strength advantage for the non-tracking tack materials was around 20-percent. Once again, Material C was the best overall performer with very high strength values and the second to the lowest standard deviation.

Table 6 – Shear Strength - Non-Tracking Tack Materials

Material	Shear Strength	
	Average (psi)	Std. Dev. (psi)
A	302	41.7
B	322	16.5
C	389	24.5
D	341	56.0
E	340	37.7
Average	**339**	**35.3**

Table 7 - Shear Strength - Conventional Tack Materials.

Material	Shear Strength	
	Average (psi)	Std. Dev. (psi)
CRS-1	282	27.9
CRS-2	285	25.3

CONCLUSIONS

Adequate bonding between bound layers is necessary for pavement performance. Through these laboratory evaluations, the following conclusions were noted:

- Trackless tack coat materials are superior to CRS-1 in terms of tracking under laboratory and oven dried conditions
- Trackless tack coat materials provide better shear strength compared to CRS-1 and CRS-2. All trackless tack coat materials had a higher average strength, but for 3 of the 5 materials the standard deviation was higher. This may be a function of the number of tests conducted per material.
- Trackless tack coat materials provided better tensile strength compared to CRS-1 and CRS-2. All trackless tack coat materials had a higher strength; all but one had a lower standard deviation.

RECOMMENDATIONS

While the laboratory results are encouraging, further validation of the materials is needed in a field environment. Each material will need to be placed per supplier's recommendations and assessed. This assessment should include subjective and objective evaluation of tracking. Cores from the pavement should be retrieved and tested for bond strength. Cores should be taken from the wheel paths where dump trucks typically remove tack during the paving operation. This information in conjunction with the laboratory results can be used to finalize the new special provision as well as populate the approved materials list for trackless tack. Finally, field evaluation of the trackless tack materials will allow VDOT to evaluate the influence of weather conditions on the material performance.

ACKNOWLEDGEMENTS

The VDOT Central Office Asphalt Lab and Virginia Transportation Research Council's Asphalt Lab was responsible for the laboratory testing and general compilation of data necessary to prepare this report. Troy Deeds and Donnie Dodds of the VTRC Asphalt Laboratories designed and constructed the laboratory-produced specimens and conducted the necessary shear and tensile strength laboratory testing. Mike Nuckols and Ken Elliton of COAL performed the much of the tracking testing. Frank Adams of COAL performed the emulsion testing. Finally, the authors would like to thank the trackless tack suppliers (Blacklidge Emulsions, Seaboard Asphalt, Hammaker East, Asphalt Emulsions, and SemMaterials (now NuStar) for their assistance and providing materials for testing.

REFERENCES

1. Virginia Department of Transportation. Special Provision for Non-Tracking Tack Coat. Richmond, 2008.
2. ASTM International. 2008. Annual Book of ASTM Standards, Vol. 4.03. West Conshohocken, PA.
3. McGhee, K.K. and T. Clark. *Bond Expectations for Milled Surfaces and Typical Tack Coat Materials Used in Virginia*. VTRC 09-R21. Virginia Transportation Research Council, Charlottesville, VA, 2009.