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Trackless Tack Coat Materials: A Laboratory Evaluation for Performance Acceptance

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Supplementary Notes:

Abstract:

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The procedures were developed and were demonstrated through an evaluation of five "trackless" tacking materials and two conventional tacking materials. The evaluation demonstrated that the trackless materials outperformed the conventional materials in the laboratory tracking test and in the bond performance tests for tensile and shear strength.

The study recommends that VDOT formalize the described laboratory procedures to produce a Virginia Test Method to qualify candidate non-tracking tack coat materials for field verification. It further recommends that VDOT formalize the field verification system and includes general direction on the elements to include in that process.

This work is part of a program of research designed to support a move to performance-oriented specifications for the interlayer bond for pavement construction. The non-tracking tack coat materials investigated in this study are expected to facilitate the improved performance of this bond and, as a consequence, the pavement system as a whole. This work supports an anticipated incremental improvement to an annual asphalt concrete program that is worth between $200 million and $400 million per year (not including new construction). When applied to investments on this scale, even nominal improvements easily translate into considerable savings.

FINAL REPORT

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Virginia Center for Transportation Innovation and Research
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

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DISCLAIMER

ABSTRACT

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INTRODUCTION

Background

During the design of a pavement structure, the engineer assumes the loads applied by traffic will be distributed in 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 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, the engineer designs for a "no slip" (i.e., bonded) condition between asphalt concrete layers, resulting in a monolithic structure. Unfortunately, the "no slip" condition is not always established during construction.

Bonding between asphalt concrete layers is provided by two methods: an adhesive bond and a mechanical bond. For most new construction and straight overlay projects, an adhesive bond is achieved through the use of a tack coat material. This material is either a neat (unmodified) or modified liquid asphalt or an asphalt emulsion (i.e., a combination of water and liquid asphalt). The tack coat provides the glue between two layers 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 create 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 adhesive bond resulting from the tack coat, provides a "no slip" interface. In situations in which the interface is a milled surface, earlier work (McGhee and Clark, 2009) demonstrated significant mechanical bond even when the adhesive bond may be suspect. Unfortunately, the interface for straight overlays provides precious little mechanical assistance.

Whether an adhesive or mechanical bond is formed, the bond is necessary in order to achieve the structural design life of the pavement. Nevertheless, the use of tack coat materials in the field is often omitted or the tack coat materials are not applied at the specified application rate. The predominant reason is to avoid excessive tracking of tack coat material onto adjacent pavements. Tracking results in buildup 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 that results from insufficient interfacial bond is much higher because of premature functional and structural pavement failures.

Non-Tracking Tack Materials

In 2005, the Virginia Department of Transportation (VDOT) was approached by a tack coat supplier with a new material: "trackless" tack. At its cost, the material supplier proposed a series of demonstration projects around Virginia. VDOT and the supplier identified paving contractors and project sites to try this new material. Essentially, the material used a very hard performance-graded binder with a positive charge, which affects its affinity to other materials. Once applied to the surface through a conventional distributor, the tack material broke (i.e., cured to an "un-tacky" state) in a matter of minutes. After a series of projects and testing by VDOT, the "Special Provision for Non-Tracking Tack Coat" was developed for use on projects (VDOT, 2008). The initial special provision stated that the tack coat needed 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. Although this special provision was available for statewide use, only isolated regions of Virginia incorporated it into their 2006 maintenance resurfacing schedules.

PROBLEM STATEMENT

Successful application of the "Special Provision for Non-Tracking Tack Coat" (VDOT, 2008) led to the emergence of a new market, and other tack coat suppliers soon began to develop other varieties of trackless tack. The materials and methods applied to produce these materials were different from those of the initial supplier. As a consequence, although many of these materials might legitimately function as a trackless tack coating, the new products could not comply with the more fundamental material requirements of the special provision. This left VDOT in an interesting predicament: force all suppliers to comply with a special provision based on a single product or evaluate each new material independently of the special provision.

The prudent thing to do was to develop a new special provision that would accommodate all tacking products that could legitimately contribute to a non-tracking paving process. Since the basic formulations differed greatly, a new special provision could hardly prescribe the fundamental material properties of every possible alternative. It could, however, establish performance criteria for laboratory assessment that paralleled the most important criteria for field performance. With performance as a basis, the new provision needed (1) to define *tracking* (and how it would be measured), and (2) to specify minimum bond strength requirements.

PURPOSE AND SCOPE

The purpose of this study was to develop, demonstrate, and document laboratory procedures VDOT could use to evaluate non-tracking or trackless tack coat materials. The procedures would be used to qualify candidate material formulations for field validation.

The scope of the study was limited to a laboratory evaluation of five candidates for approval as trackless tack coat materials and two candidates for approval as conventional tacking materials.

METHODS

Four tasks were carried out to achieve the objectives of the study:

1. An overview of VDOT's materials acceptance procedure was developed.

2. Laboratory procedures were developed to evaluate trackless tack coat materials.

3. The procedures were demonstrated using five trackless materials candidates and two conventional tacking materials.

4. The procedures were documented.

Overview of VDOT's Materials Acceptance Procedure

Located at VDOT's Central Office Materials Division, the Central Office Asphalt Lab (COAL) includes a laboratory for binder and emulsion testing. This lab is charged with performing system-wide quality assurance testing and project level quality assurance testing.

When a new material, such as a trackless tack formulation, is proposed for use on VDOT projects, COAL performs a verification sampling and testing review that starts with confirmation of the product's fundamental material properties. Once a material is accepted by VDOT (as trackless tack or other use) it is placed on VDOT's Approved Products List and these fundamental properties are monitored. As long as the material complies with the supplier's defined materials property values (minimum value, maximum value, acceptable range) and no problems are reported on projects, no additional actions are taken. However, if problems are reported in the field or lab results indicate the material has changed, additional investigation is required. Defining the material based on the supplier's criteria is an essential step in the laboratory approval process.

Development of Laboratory Evaluation Procedures

To develop the laboratory evaluation procedures for trackless tack coat materials, three primary types of tests were conducted: two were performed by COAL, and the third was performed by the Virginia Center for Transportation Innovation and Research (VCTIR). The tests were:

1. characterization of the tack coat material, i.e., material properties, based on the information provided by the supplier, performed by COAL

2. tracking of material, performed by COAL

3. bond strength, performed by VCTIR.

Each trackless tack coat material was identified with a letter from A to E. The conventional tack coat materials, used as the control in this study, were identified as either CRS-1 or CRS-2.

Characterization of Material

Several standard tests were conducted to characterize each emulsion for future quality assurance. The consistency of the submitted tack coat was determined using the Standard Test Method for Saybolt Viscosity (AASHTO T 72). The composition of each material was determined by distillation using the standard method of tests for emulsified asphalts (AASHTO T 59). The properties of the residual asphalt were characterized by use of the penetration (AASHTO T 49) and softening point tests (AASHTO T 53).

Tracking of Material

Several approaches were considered for determining the amount of tracking exhibited by a material. In addition to relevance, it was essential that the selected approach perform consistently with every product. The researchers ultimately selected the device shown in Figure 1 (ASTM, 2008). This approach is typically used to evaluate pavement marking materials,

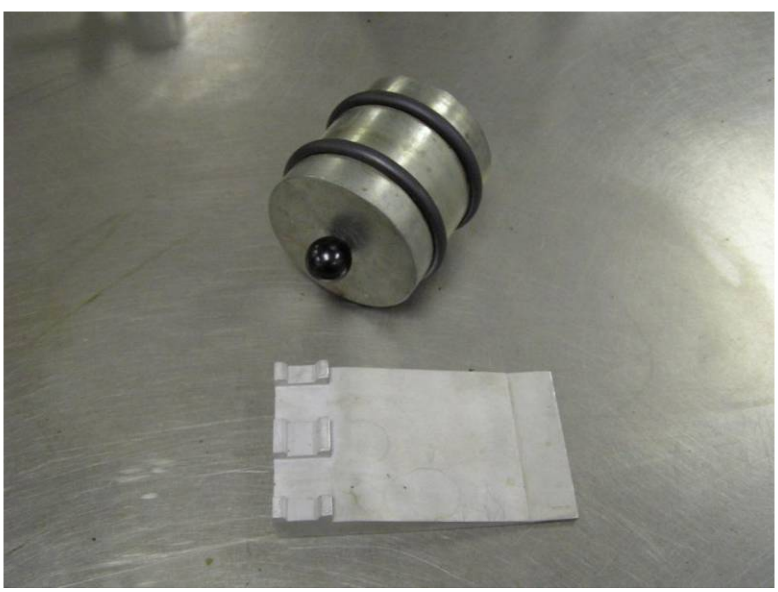

Figure 1. Tracking/Pickup Device Specified in ASTM D711

specifically epoxy traffic paint, that are applied at different thicknesses. Figure 2 shows the draw down device for applying tack at desired rate.

To quantify tracking, a visual rating scale was developed. A value of 10 was assigned for full pickup and tracking along the length of the drawdown sample. A value of 0 was assigned when no pickup 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 3 shows some typical results from the tracking tests. Example a) was given a

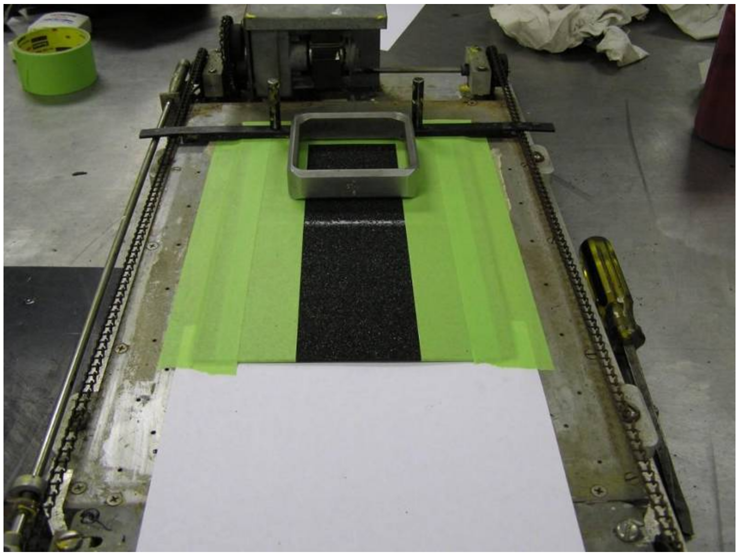

Figure 2. Draw Down Device for Applying Tack at Desired Rate

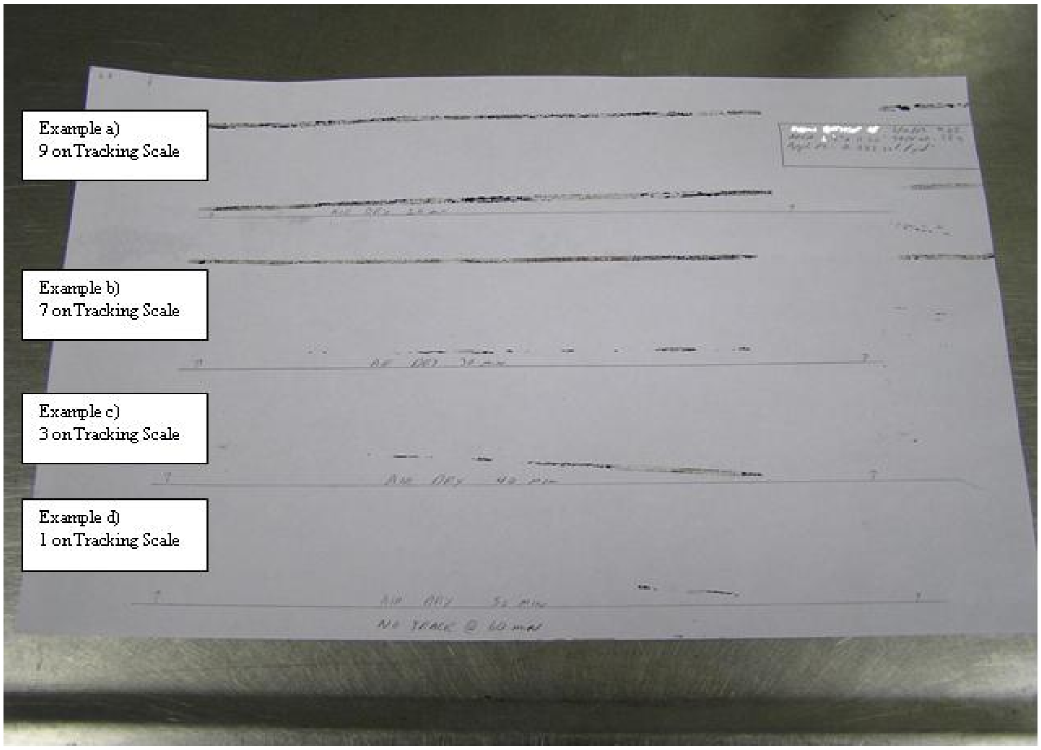

Figure 3. Tracking Scale

rating of 9 because of 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.

After working with ASTM D 711, two sets of tests were initially developed by the research team. 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 emulsified material.

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. In accordance with 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. The material was allowed to sit for predetermined periods of time. After 20 minutes, the first tracking/pickup test 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 the time of the initial tack application had elapsed. All seven tacking materials were subjected to this series of tests.

The residual application rates reported for these tests were determined from the measured mass just prior to the first pass of the tracking device (i.e., after 20 minutes). For the room temperature tests, this measurement 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 tendency of the material to track once all water had evaporated. Through use of the 0.8 mm thickness setting specified in ASTM D711, tack coat material was applied to a piece of roofing paper. 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 0.0 g 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.

Bond Strength of Material

The fundamental purpose of a tacking material is to aid in bonding together the layers of multilayer pavement systems. For the wearing surface, the tensile and shear strengths of this bond are important. As the depth of the pavement increases, the need for tensile strength outweighs shear strength because of the minimized lateral forces from braking and other turning.

The bond strength procedures are described in detail in a related and report (McGhee and Clark, 2009). 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 test specimens were constructed in a gyratory compactor using locally produced dense-graded asphalt concrete. The 2-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 was then "aged" through sandblasting and then warmed to 50º C. The tack coat material was applied at the desired rate 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 lower layer, complete with a cured tack coat surface, was then placed back into the gyratory compactor and a fresh layer of asphalt concrete 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 the 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 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 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 was 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 (ASTM, 2008). 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.

RESULTS AND DISCUSSION

Material Properties

All of the tack materials that were submitted to VDOT were tested against the supplier's material specifications. These specifications were used by VDOT in the quality 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.

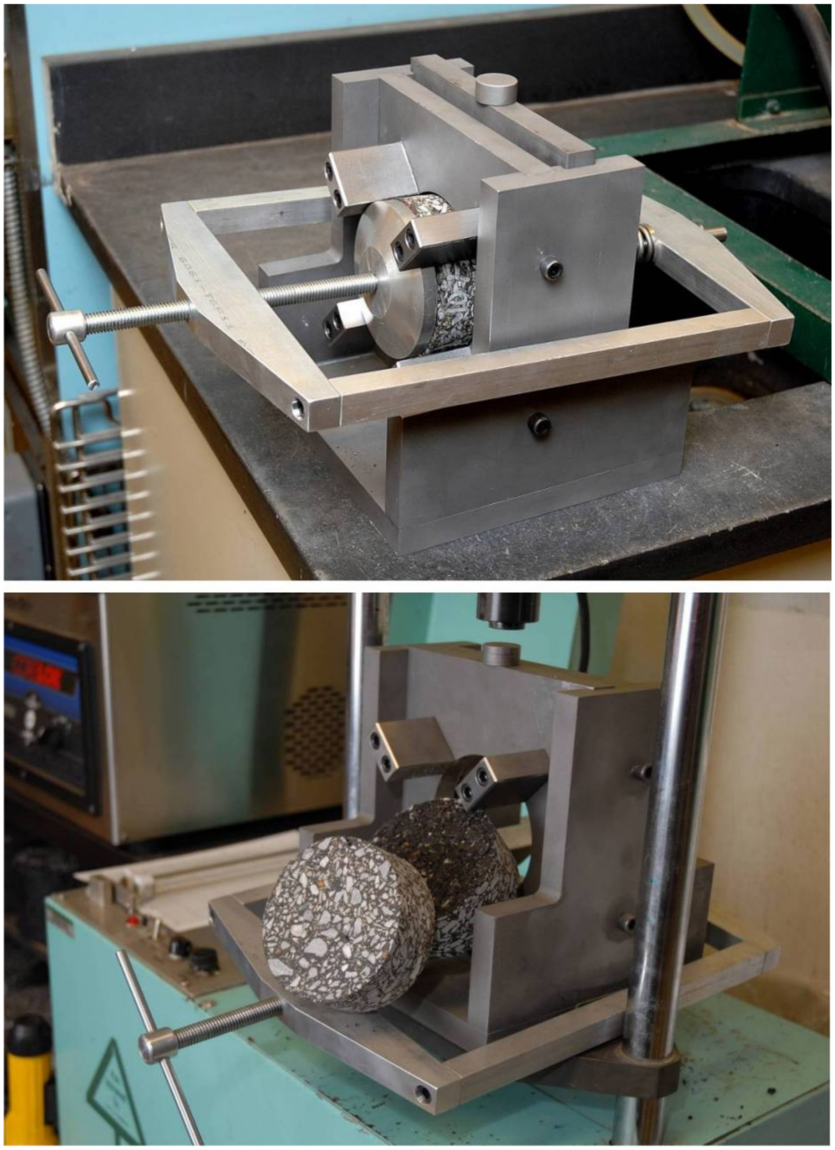

Figure 4. Shear Testing Device

Results of Lab Tracking Tests

Room Temperature Tracking Tests

Given the subjective nature of the laboratory tracking test, three raters provided independent ratings of the tracking results. The final reported rating was the average of three ratings 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	Average Residual (gal/yd^2)	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

After 1 hour, Materials A, B, and C showed no signs of tracking and Materials D and E had trace amounts of tack on the paper. Overall, none of the non-tracking materials tracked in the lab, even though the average residual material varied from 0.055 to 0.085 gal/yd^2. Interestingly, CRS-1 showed extensive tracking after 1 hour along with 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 predetermined time increment. To eliminate the possibly of decreased tracking attributable to removal of tack during previous tests, a second round of testing was performed in which three new samples were prepared for each material. One sample was tested at 40 minutes and one at 50 minutes. The same rating process was used in the second round of room temperature testing. Table 2 shows the results for all samples except Material E (the manufacturer did not provide additional material for testing). The testing for Round 2 was moved from countertop testing to an enclosed laboratory hood to reduce temperature variability, which may have affected curing time. The temperature in the hood was monitored during all testing and was maintained at 74 ± 2°F.

Table 2. Room Temperature Tracking Results (Round 2)

Material	Curing Time			
	40 min		50 min	
	Residual Application Rate (gal/yd^2)	Track Rating (0-10)	Residual Application Rate (gal/yd^2)	Track Rating (0-10)
A	0.06	0.33	0.04	0.17
B	0.11	6.00	0.10	5.00
C	0.06	0.33	0.05	0.33
D	0.08	5.33	0.07	2.33
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.

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 replicates and none on the remaining two. Overall, none of the non-tracking tacks tracked in the lab, even though the average residual material varied from 0.047 to 0.064 gal/yd^2. Once again, the 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.

Table 3. Constant Mass Tracking Results

Material	Average Residual Application Rate (gal/ yd^2)	Average Track Rating (0-10)
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

Results of Bond Strength Tests

The bond strength test results for the non-tracking tack materials are presented in Tables 4 and 6. The results for each material represent an average and a standard deviation from six 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 four 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 four products).

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

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

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

Summary

Overall, the results of the four lab tests (i.e., room temperature tracking, oven dried constant mass tracking, tensile strength, and shear strength), confirmed the superiority of the trackless tack coats in terms of tracking and the improvement in overall bond strength. Material C had the highest shear and tensile strengths and the least amount of tracking. CRS-1 and CRS-2 had lower strengths and more tracking compared to that of all of the trackless tack coat materials.

CONCLUSIONS

- *This suite of laboratory tests and procedures do an effective job of prequalifying a tack coat material for further verification through field evaluation.* ASTM D711 discriminates between those materials that pick up and track and those that are more likely to be non-tracking. The laboratory shear and tensile tests verify the potential bond strength of the alternative materials.

- *Trackless tack coat materials outperform the conventional tack material (CRS-1) in laboratory tests of tracking potential.* Compared to the conventional material, the trackless products are superior performers under both normal laboratory testing temperatures 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 three of the five materials, the standard deviation was higher. This may be a function of the number of tests conducted per material.

- *Trackless tack coat materials provide better tensile strength compared to that of CRS-1 and CRS-2.* All trackless tack coat materials had a higher strength; all but one had a lower standard deviation.

RECOMMENDATIONS

1. *VDOT's Materials Division should formalize the suite of laboratory procedures described in this report into Virginia Test Methods to be used in qualifying candidate non-tracking tack coat materials for field verification.*

2. *VDOT's Materials Division should work with VCTIR to formalize a field verification process for accepting tack coat materials for use on projects in which non-tracking paving is required (or desired).* This assessment should include practical methods for evaluating both tracking potential and bond strength. The strength test specimens (from cores) should be taken from the wheel-paths where haul trucks and other equipment typically remove tack during the paving operation.

COSTS AND BENEFITS ASSESSMENT

In the summer of 2011, VDOT moved exclusively to non-tracking paving for asphalt concrete resurfacing work. As a consequence, during peak construction season (i.e., before October 1) Virginia contractors are required to use VDOT-approved non-tracking tack coat materials. This report serves to document the laboratory elements of the rational and practical method that VDOT uses to qualify those materials.

In a broader view, this work is part of a program of research designed to support a move to performance-oriented specifications for interlayer bond for pavement construction. Much like the earlier research that addressed bond expectations for milled surfaces (McGhee and Clark, 2009), this work ultimately targets optimum bond strength and thus improved overall pavement performance. The non-tracking tack coat materials are expected to facilitate that improved performance and will also reduce or eliminate the aesthetics and safety concerns that can be part of conventional tacking operations.

Finally, to put this work in an economics context, VDOT attempts to program at least $200 million per year in maintenance-resurfacing work with asphalt concrete (not including construction). For the 2011 season, the program was closer in value to $400 million, and the program for the 2012 season is likely to be similar in size. It is difficult to place a numerical value on the overall improvement in pavement strength and performance that should come with better interlayer bonding. However, with investments of this scale, any improvement quickly translates into considerable financial savings

ACKNOWLEDGMENTS

VDOT's Central Office Asphalt Lab and VCTIR's Asphalt Lab were responsible for the laboratory testing and general compilation of data necessary to prepare this report. Troy Deeds and Donnie Dodds of VCTIR 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 much of the tracking testing. Frank Adams of COAL performed the emulsion testing. Finally, the authors thank the trackless tack suppliers (Blacklidge Emulsions, Seaboard Asphalt, Hammaker East, Asphalt Emulsions, and SemMaterials [now Road Science]) for their assistance and provision of materials for testing.

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