1. **Cover Page**

Wisconsin Highway Research Program

Investigation of Tack Coat Materials on Tracking Performance

(Final Work Plan)

Wisconsin Highway Research Program

LIMITED USE DOCUMENT

University of Wisconsin - Madison

Original Submission Date: January 20, 2017

(Work Plan Revised in April 20, 2017)

2. Summary Page

Project Title:	Investigation of Tack Coat Materials on Tracking Performance
Proposing Agency:	The Board of Regents of the University of Wisconsin System University of Wisconsin-Madison Office of Research and Sponsored Programs 21 N. Park St., Suite 6401 Madison, WI 53715-218 608-262-3822
Person Submitting the Proposal:	Hussain Bahia, PhD
Proposal Written By:	Hussain Bahia, PhD Dan Swiertz, PE *UW Madison* Louay Mohammad, PhD *Louisiana State University*
Proposal Date:	January 20, 2016 (Revised April 17, 2017)
Principal Investigator:	Hussain U. Bahia Professor Department of Civil and Environmental Engineering 3350 Engineering Hall 1415 Engineering Dr. Madison, WI 53706
Administrative Officer:	Kim Moreland Director of Research & Sponsored Programs 21 N. Park St., Suite 6401 Madison, WI 53715-218 608-262-3822
Proposed Contract Period:	18 months
Total Contract Amount:	$100,000
Indirect Cost Portion at:	15%

Technical Oversight Committee (TOC) Member Disclosure*:* None

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4. Research Plan

4.1 Background

Asphalt pavements are designed to behave as a flexible layer under loading. However, asphalt pavements are generally not constructed as one uniform layer, but rather in multiple lifts to ensure adequate compaction and smoothness in the finished pavement, among other factors. Tack coats are used to bond adjoining layers together to ensure layers react as a single, uniform layer under loading. Tack coats are also used when placing an overlay over an existing pavement surface and during the “mill-and fill” process, in which an existing depth of pavement is milled and removed from the surface and replaced with a new pavement layer. In all cases, insufficient bonding between layers can result in slippage failures as well as severe fatigue cracking relatively early in the pavement life. Similarly, applying too heavy of a tack coat can result in a low strength shear plane between adjacent layers. The application rate of the tack coat, specifically the residual asphalt application rate, is therefore critical to the success of the process (Mohammad, et al., 2012).

Based on a national survey conducted as part of the NCHRP Project 09-40: Optimization of Tack Coats for HMA Placement, the materials most commonly used for tack coat are asphalt emulsions, asphalt cement (paving grade asphalt), and cutback asphalt, although asphalt emulsions are by far the most commonly used material. Figure 1 shows the percentage of survey respondents who indicated that they use (or allow) a certain type of tack coat material multiplied by the number of responses for a given material to evaluate recent usage. In terms of asphalt emulsion, SS-1, CSS-1h, SS-1h, CSS-1, and RS-1 ranked as the most commonly used materials (Mohammad, et al., 2012). According to the December, 2016 edition of the WisDOT Construction and Materials Manual (CMM) Section 4-54.6.2.3, the acceptable tack coat materials for use in Wisconsin are MS-2, SS-1, SS-1h, CSS-1, or CSS-1h asphalt emulsions. No cutback asphalt materials are allowed for tack coat in Wisconsin. WHRP Project 09-02: Performance Evaluation of Tack Coat Materials conducted a survey of 14 Wisconsin contractors and found that of the emulsions listed in the specification, all but MS-1 are commonly used or specified in Wisconsin (Crovetti, Castedo, Ainge, & Nguyen, 2012).

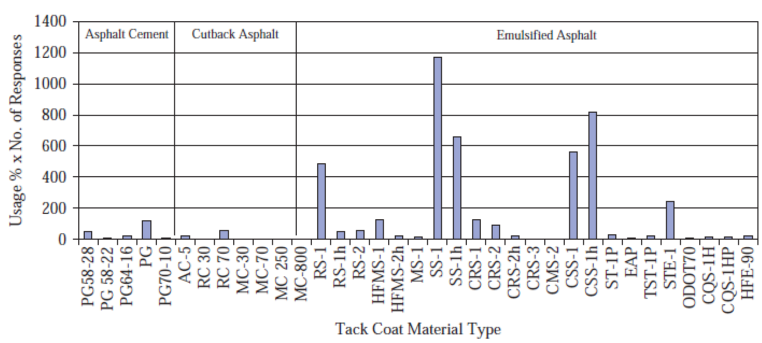


Figure 1. NCHRP 09-40 survey results for recently used tack coat materials nationally (Mohammad, et al., 2012).

One commonly encountered problem with tack coats is pickup of the tack coat material by haul trucks after placement. The tack material that is picked up is no longer available to bond the pavement layers, and is often tracked off of the project onto adjacent roadways, driveways, etc. in a process called tracking. In fact, a survey conducted as part of NCHRP Project 09-40 reported that 67% of respondents viewed “pickup of tack coat material as a continuing problem” (Mohammad, et al., 2012). As a result, several tack coat products have entered the marketplace in recent years that are marketed as “track-free” or “trackless”; these are materials that can be driven on after curing without material pickup. In addition, modifications to the paving process have also been implemented to reduce or eliminate tracking, such as the use of spray pavers and material transfer vehicles (MTV). Spray pavers are uniquely designed pavers that apply the tack coat immediately ahead of the screed so that the new asphalt mixture is placed directly on top of the freshly laid tack material.

Recent changes to tack coat specification by WisDOT have largely addressed the issue of application rate. WisDOT has recently modified their specification to include minimum residual asphalt content requirements for tack coat emulsion as well as an increased range of application rates. However, according to the RFP, the pickup and subsequent tracking of tack coat materials is now a concern to WisDOT. The purpose of this study is to verify the optimum residual asphalt application rate for tack coat in terms of bond strength between pavement layers and develop guidance on materials and methods to reduce the pickup and tracking of tack coat materials. There are a few factors that are known to affect the pickup and tracking of tack coats, among which the most important are viscosity/stiffness of the residual asphalt, the level of dilution, the tackiness of emulsion, the curing conditions, and the rate of application. It is also well documented that time of application of traffic can affect the level of pickup and tracking. The expected outcome of the project will be recommendations for revisions to the WisDOT Standard Specification, CMM, and/or Facilities Development Manual (FDM) and "practice-ready" recommendations for contractors to reduce tracking.

4.2 Research Objectives

The objective of this research is to perform a critical evaluation of the materials and application methods used in Wisconsin for tack coats in order to provide recommendations that make tack coat usage more efficient and effective. The following specific objectives have been identified by the research team:

- Determine the proper timeliness of tack coat application with consideration given to project scope (paving times, lane closures, etc.).
- Evaluate different tack coat materials to determine which product should be used based on prevailing climate and other project considerations.
- Evaluate other techniques, innovations, and technologies that may allow for greater efficiency relative to standard WisDOT practice.
- Develop recommendations for WisDOT Standard Specifications, Construction Materials Manual, and Facilities Development Manual regarding tack coat usage and best-practices.

4.3 Research Approach

The proposed research approach will start with a detailed literature review and survey of specifications in neighboring states, based on which a work plan will be developed to address the objectives of the project. After getting approval of the experimental working plan, the testing will be completed and a final report will be submitted. The following sections include the details of the work plan and tasks to complete the project.

4.3.1 Work Plan & Experimental Approach

The proposed work plan is divided into five tasks, as shown in Figure 2 and outlined in detail in the following sections. A research team consisting of the University of Wisconsin and Louisiana State University has been formed to execute the work required to achieve the objectives. In addition, an agreement with the Asphalt Technologies Group Laboratory has been reached to supply the materials needed and provide expertise in field projects, if needed. The Asphalt Technologies Group is a Division of Henry G. Meigs, LLC, a well-known supplier of asphalt emulsion tack coat materials in Wisconsin and the upper Midwest. A letter of cooperation from the Asphalt Technologies Group is attached to this proposal.

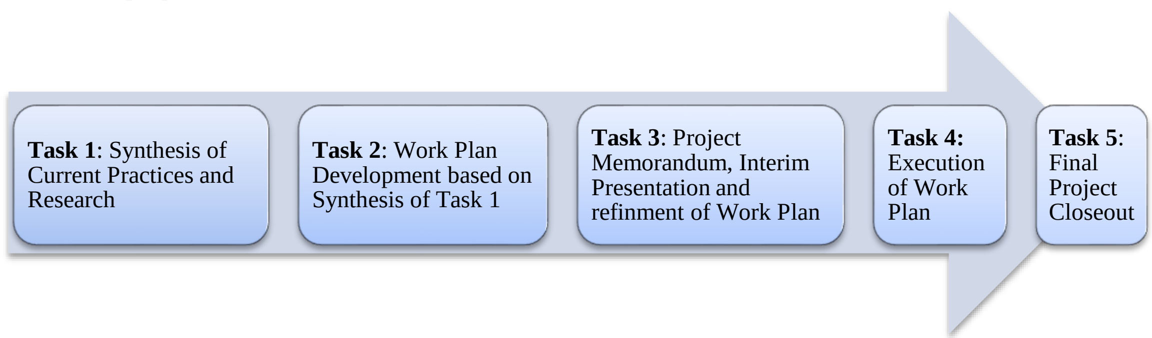


Figure 2. Proposed flow chart of work plan

Task 1: Synthesis of Current Research & Literature and Specification Review

Work during this task will focus on identifying ongoing and completed research addressing tack coat materials and practices with emphasis on practices for cold weather regions like Wisconsin. According to WisDOT specification, five types of emulsified asphalt are allowed for use as tack in Wisconsin: MS-2, SS-1, SS-1h, CSS-1, or CSS-1h. It is expected that an initial step of this research will be to verify which of these materials are most commonly used by contractors using project records or direct surveys; WHRP Project 09-02 found that all but MS-1 are commonly specified and used (Crovetti, Castedo, Ainge, & Nguyen, 2012). The outcome of this process will be to identify which materials should be the focus of the laboratory work in this study. In addition, tack coat specifications from surrounding Agencies will be reviewed to determine whether other materials should be included in the experimental design for comparison. With the recent increased popularity of trackless tack materials, these materials will also be included in the experimental design for comparative purposes.

A major component of this work will be the assessment of bond strength and bond quality between pavement layers. Several test methodologies exist to measure bond strength, but none are commonly used in Wisconsin. The research team will therefore evaluate existing methods based not only on their ability to measure bond strength/quality, but also on their ease of use, cost, applicability to field materials, repeatability, and whether or not a standard specification is in place for the method. The WHRP 09-02 project developed two tests for evaluation bond strength, a direct shear and rotational shear tester. Both devices produced generally logical results, but require the production of ‘tiered’ specimens (specimens with non-uniform cross sectional areas) and are not standardized at this time.

A central study identified in the initial literature search that includes an extensive review several of these tests is NCHRP Report 712: Optimization of Tack Coat for HMA Placement, which is a product of NCHRP Project 09-40. The outcome of that project was the development of two standardized testing devices: the Louisiana Tack Coat Quality Tester (LTCQT), standardized as AASHTO TP115-16, and the Louisiana Interlayer Shear Strength Tester (LISST), standardized as AASHTO TP114-16. The LTCQT device can be used in the field or laboratory and is intended to measure the application quality of the tack coat by means of tensile pull-off strength. The LISST device is intended to measure the interlayer shear strength of cylindrical specimens, either pavement cores or laboratory produced specimens (Mohammad, et al., 2012). Typical outputs for each test are shown below.

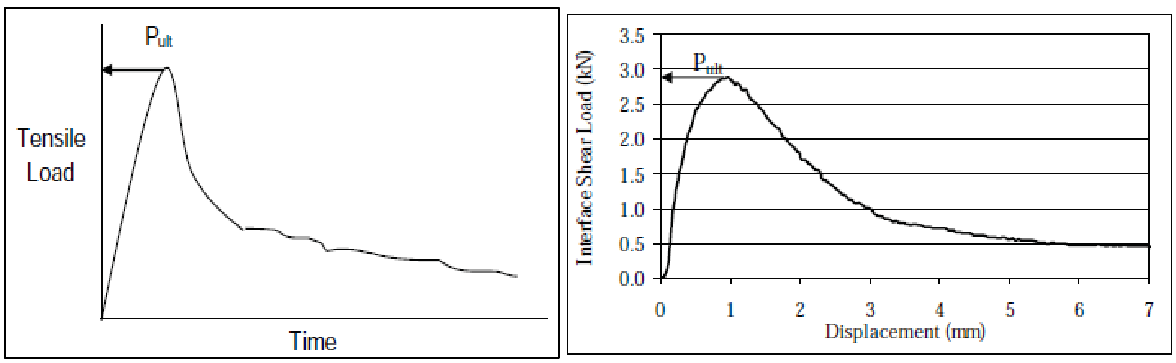


Figure 3. Typical output of LTCQT (left) and LISST (right) (Mohammad, et al., 2012).

The LTCQT device is non-destructive, so the evalaution of tack coats in the field at the time of contruction is possible. This device may also offer a means to quantify when an emulsion has reached the maximum bond strength (cured), which may be correlated to its propensity to pick up and track. The LISST device has the ability to run both 4” and 6” cores or laboratory produced specimens, so the results can be used for verification testing of in-place materials. The LISST device has been used for several types of pavmenets surfaces, including new HMA, milled, HMA, and PCC. The two devices could be used in tandem to measure the quality of application via the LTCQT and the verification of bond adequacy using the LISST (Mohammad, et al., 2012).

A second area of research in this project will be in the evaluation of tracking of tack coat materials. No AASHTO/ASTM standardized methods of measuring tack coat tracking were found in the initial literature search; however, several developmental methods exist in the U.S. and abroad. Dynamic Shear Rheometer based tackiness tests have been used in the literature to measure the adhesion and cohesion of asphalt binders (Figure 4) in a similar fashion to the LTCQT described above. It is envisioned that asphalt emulsion residue can be loaded into the DSR and a normal force (or constant normal strain rate) could be applied and the resulting strain (or force) could be used to quantify an adhesion index. Using such a test, Kanitpong (2005) developed a parameter called the tack factor, which was found to be sensitive to asphalt binder modification, although testing was not conducted on asphalt emulsion residue. More recently, work presented at the 2017 Transportation Research Board Annual Meeting used a similar DSR based test on tack coat residue to measure tracking potential of several different types of emulsions. The work is an extension of a project funded by the Texas Department of Transportation “Performance Evaluation and Specification of Trackless Tack.” Findings suggest that the test is sensitive to emulsion residue properties and can rank different materials based on their propensity to track (Wilson, Seo, & Sakhaeifar, 2016; Seo, Sakhaeifer, & Wilson, 2017). A similar test may be a useful screening tool in this study to evaluate the adhesion and failure properties of different asphalt emulsion residue.

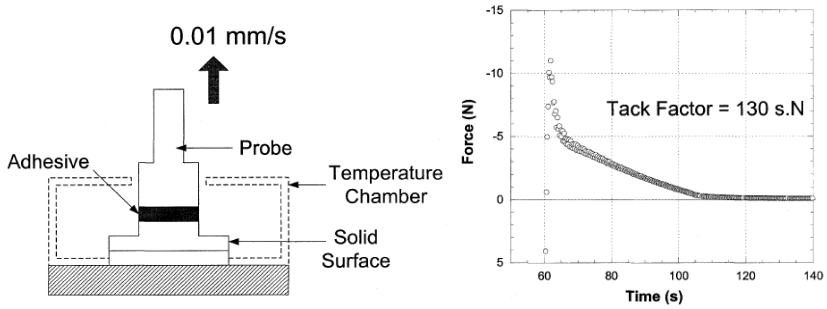
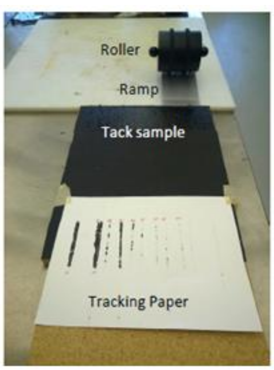


Figure 4. Tack Test in the Dynamic Shear Rheometer (Kanitpong, 2005).

A modified version of ASTM D711: No-Pick-Up Time of Traffic Paint has been applied to successfully test tracking potential in asphalt emulsion tack coats. The test involves drawing a sample of asphalt emulsion using a wet film applicator on asphalt roofing felt and curing the sample in prescribed conditions. Every 10 minutes during curing, an 11.9 lb. roller outfitted with two rubber O-rings is rolled across the sample and over a white piece of paper. This is repeated until no tracking onto the white paper is observed. The tracking observed is ranked on a scale according to Figure 5 below. Wilson et al. (2016) successfully used this test to discriminate between conventional and trackless tack types. Based on testing at several curing conditions, the research team envisions that a 'Track-Free Time Chart" can be produced that allows users to enter local climatic conditions and material type to determine the time after application that the material is track free.

The advantages to such a test are that it is currently used in the traffic paint industry and has been successfully applied to asphalt emulsions. Second, since the test is standardized in the paint industry, the equipment is available at relatively low cost. Finally, the equipment is portable and relatively compact, so curing samples in an environmental chamber or in different conditions is possible.

Wilson et al. (2016) and findings from NCHRP Report 712 clearly show that the rheological properties of the asphalt emulsion residue can be correlated with tack coat performance. As such, it is envisioned that for this project, the residual asphalt from several emulsion products will be tested to determine whether a simple surrogate for performance, such as softening point, can be identified. In addition, the asphalt emulsion properties will also be evaluated according to AASHTO T59. It is presently contemplated by the research team that a combination of the performance tests described above in conjunction with rheological characterization of the asphalt emulsion residue will provide the necessary information to accomplish the project objectives. A preliminary work plan to accomplish this work is provided below.



Description	Example	Multiplication Factor
Heavy		1.0
Moderate-Heavy		0.75
Moderate		0.5
Low		0.25
None		0

Figure 5. Modified No-Pick-Up Time Test for asphalt emulsion tack coats (Wilson, Seo, & Sakhaeifar, 2016).

More recently NCHRP Project 09-50 was completed and NCHRP Report 837 was published in February of 2017 (Kim et. al 2017). In this report ASTM D3121-16: Tack of Pressure-Sensitive Adhesives by Rolling Ball was proposed as a method to estimate time required to resist tacking for spayed seals. This test method involves rolling a standard steel ball down an inclined ramp and measuring the distance the ball rolls across the emulsion. As the emulsion's tackiness decreases with curing time, the distance the ball rolls is expected to increase.

Task 2: Development of Work Plan

The work plan for this project will be finalized after completing Task 1 activities. It is expected to include two main parts:

- Validation of the application rates recommended by WHRP Project 09-02 and currently specified by WisDOT based on literature review and detailed analysis of the results of NCHRP Project 09-40;
- A laboratory or field tracking study to evaluate the effect of material types and constructability factors (including curing time) that influence tracking behavior, and application of the assessment methodology to field projects as identified in the RFP by WisDOT.

Materials commonly used for tack coat in the State of Wisconsin will be sampled from several vendors and emulsions with known residue properties will be created in the laboratory as control samples. "Non-spec" materials will be included, if needed, based on guidance from the POC. Cores from pilot projects will serve to calibrate the laboratory study to the field. The following sections provide details of the two tasks.

Part 1: Validation of Asphalt Emulsion Application Rates

The 2017 WisDOT Standard Specification for Construction Section 455.3.2 specifies that the tack coat material may be diluted, but that the residual asphalt content in the diluted product must be equal to, or greater than, 50% residual asphalt. According to the specification, the diluted material application rate is 0.050 to 0.070 gal/yd^2 unless otherwise specified. Guidance in the CMM suggests using an initial application rate of 0.050 gal/yd^2 for new surfaces and 0.070 gal/yd^2 on older and milled surfaces, but to adjust the rate as needed after observation. Using an assumed 50% residual asphalt content, this range corresponds to a range in residual asphalt application rates of 0.025 to 0.035 gal/yd^2. Recommendations from NCHRP Project 09-40 are also based on residual asphalt application rate and depend on the pavement surface type or condition of the underlying layer, as shown in Table 1.

Table 1. Recommended Residual Asphalt Application Rate for Tack Coat (Mohammad, et al., 2012).

Surface Type	Residual Application Rate (gsy)
New asphalt mixture	0.035
Old asphalt mixture	0.055
Milled asphalt mixture	0.055
Portland cement concrete	0.045

Based on the rates listed in Table 1, the application rates specified by WisDOT are on the low end of the recommended range for new pavement surfaces and appear to be significantly low for older and milled surfaces. To determine whether the specified rates produce similar results to those used to develop the guidance in Table 1, and to provide a baseline for field core testing, a detailed analysis of the results in NCHRP 09-40 will be carried out to determine if the increase in application rate and if the allowed dilution procedure should be revised.

Based on the analysis, limited laboratory testing of the emulsions could be carried out to confirm that the materials used in Wisconsin projects have similar characteristics to the materials tested in the NCHRP project. The objective of the emulsion residue testing will be to determine if asphalt residue properties can be used to predict tack coat performance, and to establish a range in properties that can be used as specification requirements based on the surface type and the application rate.

For example, a potential criteria is to use the asphalt emulsion residue rheology to predict performance. As shown in NCHRP 09-40, the Superpave rutting parameter $G^*/\sin(\delta)$ is related to the interface shear strength measured between two asphalt mixture samples, shown in Figure 6 (Mohammad, et al., 2012). The data clearly shows that the shear strength increases with the application rate and that for all application rates, a higher $G^*/\sin(\delta)$ results in higher shear strength. It is therefore postulated that a threshold might exist to ensure a specific tack coat material might perform acceptably in the field. Since this project may also involve field cores, partial field validation of the concept may be possible.

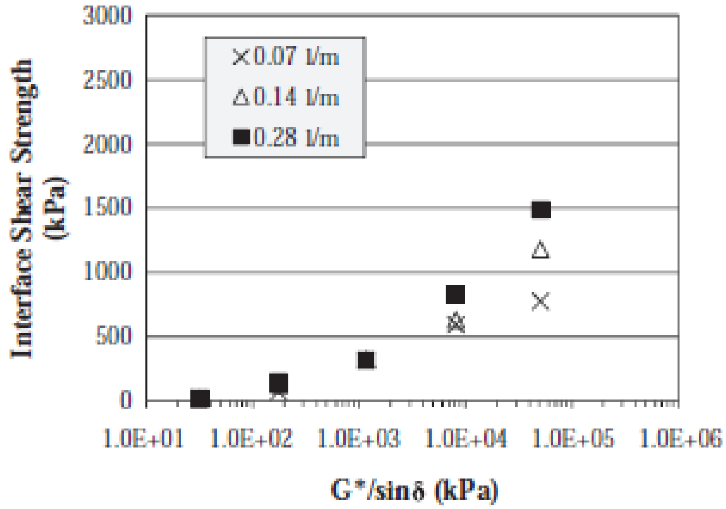


Figure 6. Relationship between G*/sin(δ) and ISS for three CRS-1 application rates (Mohammad, et al., 2012)

According to the RFP, WisDOT will provide field cores from pilot projects in 2017. Tack coat application rate and mix design data from the pilot projects can be used in conjunction with testing the cores according to AASHTO TP114 using the LISST device to validate the criteria developed based on the emulsion residue properties. Table 2 provides a list of candidate factors that could be considered for selecting the field cores from the 2017 WisDOT projects.

Table 2. Preliminary Experimental Design for Validation of Residual Asphalt Application Rate and Emulsion Type

Factor	Level	Explanation
Existing Surface Condition	2	New Pavement or old with no milling; Old Pavement (milled surface);
Existing Surface NMAS*	2	12.5 mm , 19 mm Based on most commonly used NMAS in Wisconsin
Tack Coat Residual Application Rate	2	0.020 gal/yd^2, 0.050 gal/yd^2 Selected to include WisDOT specified range and NCHRP recommendations
Tack Coat Materials	3	Based on contractor survey, but expected to include: CSS-1, CRS-1, trackless
Application/Curing Condition	NA	Recorded as applied in the field
Testing Temperature	NA	Recorded as applied in the field
Total Combinations	Target 15 combinations to meet the maximum allowed cores allowed in RFP	

*The 19 mm NMAS may be evaluated as a partial factor since field cores may not be available for older 19 mm NMAS pavements that are not already overlaid with 12.5 NMAS or finer mixtures.

The findings from this study can provide insight into the feasibility of using the emulsion residue properties in Wisconsin to evaluate tack coat bonding and to predict field performance. It should be also mentioned that the NCHRP 09-50 final report has just been released and it includes some recommendations for testing the quality of Tack Coats. Table 3 is copied from NCHRP Report 837 (2017). As shown, ASTM D3121 is used to measure tracking and a viscosity test in the Rotational Viscometer is used to measure spray-ability and drain-out. These new concepts will be evaluated for this study to evaluate the emulsions used in the field projects.

Table 3. NCHRP 09-50 Proposed Tests for Sprayed Emulsions (NCHRP Report 837)

Proposed Test Methods	Proposed Testing Temperature (°C)
Storage Stability Modified AASHTO T 59 Measured responses - Rotational Viscosity, η, A – 24-hour separation ratio (Rs): 0.5 to 1.5 B – 24-hour stability ratio (Rd): Max. 1.5	25
Sprayability Modified AASHTO TP 48 Measured response – Viscosity @ 3 shear rates, Max.100 cP @ high shear rate (150 rpm)	25
Resistance to Drainout Modified AASHTO TP 48 Measured response – Viscosity @ 3 shear rates, Min.100 cP @ low shear rate (5 rpm)	25
Curing Time to Resist Tracking Modified ASTM D 3121 Measured response: rolling distance, Time to 25 cm rolling distance	25
Demulsibility AASHTO T 59 Measured response: % demulsibility Min. 40% (anionic) Min. 60% (cationic)	25
Particle Charge AASHTO T 59 Measured response: particle charge Positive (cationic)	25
Sieve Test AASHTO T 59 Measured response: % mass Max. 0.1%	25
Solubility AASHTO T 44 Measured response: % solubility Min. 97.5%	25
Float AASHTO T 50 Measured response: float time Min. 1200 seconds	60
Percent Residue AASHTO PP 72 Measured response: % residue Min. 55%	25

Part 2: Field and Laboratory Tracking and Tack Coat Quality Study

The purpose of this part of the project will be to determine the materials and constructability factors that influence the tracking potential of tack coats. As mentioned in Task 1, several test methods have been identified in an initial literature search that may show potential in identifying tracking behavior of tack coats. The rolling ball test (ASTM D3121) recommended in NCHRP 09-50, a modified traffic paint tracking test (ASTM D711), and/or a DSR-tackiness test described in Task 1 will all be considered. The testing could include testing for tracking every 10 minutes until no tracking is observed; therefore, the needed curing time to prevent excessive tracking is one of the important outcomes of the tests.

Tack coat materials considered in this project will be representative of materials in use in Wisconsin and that could provide direct comparison of the effects of residue properties and modification. For example, the difference between CSS-1 and CSS-1h is principally the base asphalt binder used in production, with CSS-1 typically produced with PG 58-28 as the base asphalt and CSS-1h produced with PG 64-22 as the base asphalt. Conversely, the difference between CSS-1h and SS-1h is expected only to be the chemistry of the emulsifier; cationic emulsions are known to break and cure at a faster rate relative to anionic emulsion. The reactivity of the emulsion (comparing CRS-1 to CSS-1) may impact the timing of curing. Finally, a modified emulsion is included to determine whether polymer (or latex) modification can reduce tracking behavior. A commercial trackless tack product will be included as a control and emulsions that do not meet the current specifications but has been reported to perform well will be considered. A preliminary experimental plan for this study is shown in Table 4.

The rate of curing for emulsions, and thus potential tracking, is dependent on factors such as application rate, substrate temperature, relative humidity, and wind speed. An environmental chamber can be used to control temperature and humidity at several levels each.

Table 4. Preliminary Experimental Design for Tracking Study

Factor	Level	Explanation
Tack Coat Application Rate	2	Determined based on findings from Subtask 2 NCHRP 712 and WisDOT (0.035 and 0.050)
Tack Coat Materials*	4 will be selected	Based on contractor survey, but expected to include some of the following: CSS-1, CRS-1, CSS-1h CSS-1hL (or CSS-1hP),SS-1h Trackless (Proprietary)
Curing Temperature	2	Based on average Spring, Summer, Fall pavement temperatures for selected project location or otherwise agreed upon temperatures
Curing Humidity	2	Low and High based on relative humidity in Wisconsin during Summer and changes when raining
Surface Type	2	Milled and not milled
Total Combinations	64 combinations for Tracking and residue tests, and 16 combinations for bond strength test	

*A subset of materials may be tested in an undiluted state to evaluate the curing characteristics of diluted vs. undiluted emulsion.

Based on the findings from the tracking test, it is anticipated that the research team will attempt to correlate tracking propensity with rheological indicators of the emulsion residue at a given temperature. For example, it is envisioned that binder $G^*/\sin(\delta)$ or the Jnr from the MSCR could be strongly related with the propensity of residue to track at any given temperature. If such a correlation can be found, it may limit the tack materials specified for a project in summer to emulsions containing harder ('h') residue, for example. In addition, since two levels of each environmental condition will be tested, a 'Track-Free Time Chart" could be produced. A hypothetical example of such a chart is shown in Table 5.

Table 5. Hypothetical Track Free Time Chart for a Given Emulsion.

Pavement Temperature, °F / Relative Humidity, %	Low	High
Low	90	132
High	55	81

The testing for the laboratory study will include a set of binder residue testing and shear testing of core samples, or asphalt mixture samples fabricated in the lab. The following tests shown in Table 6 will be considered during this study. The final selection will be made after completing the literature review and the first part of Task 2 detailed above.

Table 6. Test Methods Proposed for Consideration

Testing on Emulsion/Residue or Mixture/Core	Test Methods Proposed for Consideration
Tracking Test	ASTM D3121 - Tack of Pressure-Sensitive Adhesives by Rolling Ball ASTM D711 - No-Pick-Up Time of Traffic Paint1 Others identified in the literature
Mixture/Core	Primary: Louisiana Tack Coat Quality Tester (LTCQT) – AASHTO TP115-16 Louisiana Interlayer Shear Strength Tester (LISST) – AASHTO TP114-16 Secondary: WHRP 09-02 Shear Device NCAT Shear Device, and Florida DOT Shear Test
Emulsion/Residue	Emulsion: AASHTO T59 Residue*: Full suite of Superpave M320/M332 Testing & recommendations from NCHRP 09-50 Penetration, and Softening Point

*Residue recovery methods will focus on low temperature evaporative methods

Task 3: Interim Presentation and Project Memorandum

Based on the findings from the initial literature search a Project Memorandum will be delivered in which the details of the work plan and justification for the experimental designs for each part is given. After delivering the Memorandum, a presentation will be scheduled with the POC for discussion and feedback. The feedback will be used for refinement of the work plan and a final work plan will be submitted for approval.

Task 4: Execution of Final Work Plan

With the exception of the mixture and core testing, all laboratory testing will be conducted at the UW or Asphalt Technologies Group laboratories when needed. Initially, it is planned that mixture/core testing will take place at LSU laboratory under supervision of Dr. Louay Muhamad. However, the feasibility of using the mixture/core testing devices at the UW laboratory will be explored as well. The Asphalt Technologies Group Laboratory will also be responsible for laboratory production of emulsion and supply of the base asphalt; Asphalt Technologies group is a fully AASHTO accredited emulsion testing laboratory. For a complete listing of laboratory certifications and personnel qualifications, see Sections 7, 9, and 10.

Task 5: Final Project Closeout

Based on the findings from Tasks 1 through 4, the final project report and closeout presentation will be drafted and submitted during this task. Based on the comments on the draft final report and the discussions during the presentation, the final report will be revised and submitted for final approval.

4.3.2 Expected Contribution from WisDOT Staff

Per the RFP, a maximum commitment of 40 hours by WisDOT staff and TOC members is expected for this project, primarily in discussions for development of the final work plan and the technical review of findings and reports.

4.3.3 Other Equipment and Materials

No major equipment or materials purchases are anticipated in order to fulfill this proposal. It is not anticipated that any WisDOT equipment will be needed as part of this study.

4.4 Anticipated Research Results and Implementation Plan

The anticipated result of this research project will be a final report documenting the findings as well as a recommended assessment methodology for evaluating tack coat materials in Wisconsin. This will be presented in a technical memorandum format as an appendix to the final report. The findings will directly impact designers, contractors and emulsion producers conducting work in the State of Wisconsin. Specific research results will attempt to include the following items:

1. Validation of specified tack coat materials and rates using mixture testing.
2. A simple surrogate procedure on emulsion residue or cores to estimate shear strength of the tack coat.

3. A summary of the factors influencing tracking and a 'best-practices' methodology for reducing tracking. A Track Free Time chart may be developed.
4. Assessment methodology in technical memorandum format for evaluating tack coat materials.
5. Recommendation for potential changes to WisDOT Standard Specifications and Materials Manuals.

5. Time Requirements/Schedule

The total project duration is 18 months, consisting of approximately 15 months for research and an additional three months for review and approval of final project deliverables. The anticipated start date is June 1, 2017. Based on this timeframe, the project schedule is provided in Table 7**Error! Reference source not found.** The proposed schedule or TOC meetings and submission of deliverables are denoted by the codes D and M. In addition to the deliverables provided in the schedule, the research team will submit quarterly reports according to WisDOT guidelines.

Table 7. Project Schedule

Task	**Quarter**					
	1	**2**	**3**	**4**	**5**	**6**
	6/17-8/17	**9/17-11/17**	**12/17-2/18**	**3/18-5/18**	**6/18-8/18**	**9/18-11/18**
1. Synthesis of Current Practices and Research	M1					
2. Work Plan Development		D1				
3. Interim Presentation			M2			
4. Execution of Work Plan					D2	
5. Final Project Deliverables and Closeout						D3,M3

Summary of Deliverable and Meeting Codes:

- **M1:** Project kick-off meeting held with Project Oversight Committee
- **D1 :** Project memorandum
- **M2:** Interim presentation at full TOC meeting or to POC only
- **D2:** Submission of draft final report and other project deliverables.
- **D3, M3:** delivery of final report, and Project closeout presentation to full TOC.

A research team consisting of UW-MARC staff and staff from the LSU/LTRC in Louisiana, and representatives from the Asphalt Technologies Group (cooperative agreement attached) will be assembled. The team has extensive experience with emulsion and residual binder testing and has actively participated in the NCHRP 9-50 project. LSU/LTRC was the lead contractor for the NCHRP Project 9-40 and have extensive experience in bond strength testing. In addition, Asphalt Technologies Group has with a wide range of experience in production, use, and testing of tack coats. The research team and specific involvement in the project is described Table 8.

Table 7. Summary of Research Team and Responsibilities

Team Member	Role	Responsibilities
Dr. Hussain Bahia	Principal Investigator	• Project Management and Reporting • Communication with TOC • Detailed Analysis of Data • Preparation of Project Deliverables • Development of Implementation Plan
Dr. Louay Mohammad	Management of Mixture Testing / Implementation Consultation	• Technical consulting and review • Coordination of tack coat mixture/core testing • Detailed Analysis of Data • Review of project deliverables
Mr. Dan Swiertz, PE	Management of Emulsion and Tracking Testing	• Development of Work Plan • Coordinate laboratory emulsion production/raw materials acquisition • Oversight of Testing and Data Analysis • Preparation and Review of Project Deliverables

In addition to the personnel listed in Table 8, a graduate student and the support of undergraduate hourly staff was budgeted for the UW team to support materials testing and sample preparation. The distribution of hours by task for the UW MARC team is provided in Table 8.

Table 8. Project Team – Distribution of Hours by Task

INDIVIDUALS	TASKS					TOTAL HOURS
	1	2	3	4	5	
PI: Hussain Bahia	5	19	9	47	14	94
Researcher: Dan Swiertz	31	31	16	62	16	156
Graduate Student & ATG Staff	216	87	43	433	87	866
Hourly Student	0	0	0	141	35	176
TOTALS	252	137	68	683	151	1292

6. Project Budget

Work Effort by Task

	TASK					Total	Fringes	Total Salaries and Fringes
Personal	1	2	3	4	5			
Hussain Bahia	$ 424	$ 1,696	$ 848	$ 4,241	$ 1,272	$ 8,482	$ 3,367	$ 11,849
Researcher	$ 750	$ 750	$ 375	$ 1,500	$ 375	$ 3,750	$ 1,489	$ 5,239
Graduate Student & ATG staff as needed	$ 5,034	$ 2,013	$ 1,007	$ 10,067	$ 2,013	$ 20,135	$ 4,732	$ 24,867
Hourly worker	$ -	$ -	$ -	$ 1,551	$ 388	$ 1,939	$ 64	$ 2,003
TOTALS	$ 6,208	$ 4,460	$ 2,230	$ 17,359	$ 4,049	$ 34,305	$ 9,652	$ 43,957

						Year 1	Year 2	Totals
Total Salaries, Wages and Fringes	$ 7,857	$ 5,904	$ 2,952	$ 22,056	$ 5,188	$ 27,741	$ 16,216	$ 43,957
Sub-Contracts								
Louisiana State University	$ 3,000	$ 6,000	$ 3,000	$ 12,000	$ 6,000	$ 18,000	$ 12,000	$ 30,000
Subtotal	$ 3,000	$ 6,000	$ 3,000	$ 12,000	$ 6,000	$ 18,000	$ 12,000	$ 30,000
Other Direct Costs								
Tuition Remission (Graduate Student)	$ 3,000	$ 3,000	$ -	$ 6,000	$ -	$ 6,000	$ 6,000	$ 12,000
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Subtotal	$ 3,000	$ 3,000	$ -	$ 6,000	$ -	$ 6,000	$ 6,000	$ 12,000
Materials and Supplies								
Containers, Shiiping, Laboratory Supplies	$ -	$ -	$ -	$ 650.00	$ -	$ -	$ 650	$ 650
	$ -	$ -	$ -		$ -	$ -	$ -	$ -
Subtotal	$ -	$ -	$ -	$ 650.00	$ -	$ -	$ 650	$ 650
Travel								
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Subtotal	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Communications								
Printing, Telecommunications	$ -	$ -	$ -	$ -	$ 350	$ -	$ 350	$ 350
	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Subtotal	$ -	$ -	$ -	$ -	$ 350	$ -	$ -	$ -
TOTAL DIRECT COSTS	$ 13,857	$ 14,904	$ 5,952	$ 40,706	$ 11,538	$ 55,066	$ 31,891	$ 86,956
TOTAL INDIRECT COSTS (Provide Rate and Base)	$ 2,079	$ 2,236	$ 893	$ 6,106	$ 1,731	$ 8,260	$ 4,784	$ 13,043
TOTAL CONTRACT COST	$ 15,935	$ 17,140	$ 6,845	$ 46,811	$ 13,269	$ 63,326	$ 36,674	$ 100,000

Budget Justification

1. **Staff Benefits**
   a. **Fringe Benefit Rates:** All fringe benefit rates included in the budget are in accordance with the current rates established by the UW-Madison Office of Research and Sponsored Programs. More information is available at (https://www.rsp.wisc.edu/rates/index.html).
   b. **Tuition Remission:** UW-Madison Office of Research and Sponsored Programs Notice 2006-3 requires an annual tuition remission of $12,000/yr. for graduate students assigned to the project. The proposed budget includes full tuition remission for one graduate student supported over one calendar year, i.e. $12,000. Although the student will be involved for more than one year, the tuition remission will be shared by another project.
2. **Materials and Supplies - $650 (0.65% of project budget)**
   a. **Containers and shipping:** The proposed study requires collection of cores/preparation of gyratory pills. It is presently contemplated that mixture testing will take place at LSU. Therefore, funds were allocated to transport the materials from the University of Wisconsin to Louisiana State University.
   b. **Miscellaneous laboratory supplies:** The proposed study requires a significant amount of laboratory testing. Therefore, funding was allocated to purchase laboratory supplies that will be allocated towards preparation of materials for testing.
3. **Communication - $350 (0.35% of project budget)**
   a. Funds were budgeted for communication and printing of formal documents. The RSP requires printing of seven hard copies of a final report to be submitted at the end of the contract date.
   b. It is also anticipated that various conference calls will be required between UW and LSU.

7. Qualifications of the Research Team

Hussain U. Bahia – ***Principal Investigator – UW Madison***
Dr. Bahia received his Ph.D. degree in the area of Pavement Materials and Design from the Pennsylvania State University in 1991. He joined the faculty at the University of Wisconsin-Madison in 1996 to teach and conduct research in the area of pavement materials and design. Prior to joining the UW faculty he served as the Director of Research and Engineering Services of the Asphalt Institute in 1995- 1996. He also served for four years after earning his Ph.D. on the faculty of Penn State University from 1991 to 1994. He has served as the PI or co-PI on several Wisconsin DOT projects (more than ten major studies), projects with the FHWA (four major studies), and numerous projects funded by private industry (more than twenty studies). He is has served as the PI for the NCHRP 9-10 project from 1996 to 2000 and the NCHRP 9-45 project from 2007 to 2011. Notably, Dr. Bahia is a subcontractor on NCHRP 09-50, which is attempting to create a performance grading procedure for asphalt emulsions. In addition to technical involvement with WisDOT and FHWA, Dr. Bahia served as the Technical Director of WHRP from 2004 – 2012 and is thus aware of the mission of the WHRP program and experienced in administration of projects funded by WHRP.

Louay Mohammad – ***Co-Principal Investigator – Louisiana State University***
Dr. Mohammad received his Ph.D. in civil engineering from Louisiana State University in 1989 and is Professor of Civil and Environmental Engineering and holder of the Irma Louise Rush Stewart Distinguished Professor in the Department of Civil and Environmental Engineering at LSU and Director of the Engineering Materials Characterization Research Facility of the Louisiana Transportation Research Center. Dr. Mohammad served as the principal or co-principal investigator on more than 58 research projects totaling over $12.7M. His projects are sponsored by NCHRP, FHWA, LADOTD, NSF, industry, etc. Dr. Mohammad and his research group developed many standard tests and mechanistic models that have impacted pavement materials characterization and performance, and contributed to implementation of the State-of Practice of asphalt mixture design through changes in asphalt specifications. Results from recently completed research projects have yielded three standard test procedures (AASHTO TP 114 Determining the Interlayer Shear Strength of Asphalt Pavement Layers, AASHTO TP 115 Determining the Quality of Tack Coat Adhesion to the Surface of an Asphalt Pavement in the Field or Laboratory, and ASTM D8044 Evaluation of Asphalt Mixture Cracking Resistance using the Semi-circular Bend (SCB) Test at Intermediate Temperature) that characterize the performance of interlayer bond strength, tack coat quality, and intermediate temperature performance of asphalt mixtures, respectively. Another recently completed NCHRP Project 20-07/Task 361 resulted in a major revision to AASHTO T 324 Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt. It is worth mentioning that ASTM D8044 (LADOTD TR 330) is included

in the 2016 Louisiana Specifications for Roads and Bridges. . Dr. Mohammad was the PI for the recently completed NCHRP Project 9-40 on the Optimization of Tack Coat for HMA Placement, NCHRP Project 9-48 on Field versus Laboratory Volumetrics and Mechanical Properties, NCHRP Project 20-07/Task 361on Hamburg Wheel-Track Test Equipment Requirements and Improvements to AASHTO T 324, and CO-PI for NCHRP Project 9-49A on Performance of WMA Technologies: Stage II – Long-term Field Performance and NCHRP Project 10-84 on Modulus-Based Construction Specification for Compaction of Earthwork and Unbound Aggregate. He is currently the PI for NCHRP Project 9-40A on Field Implementation of the Louisiana Interface Shear Strength Test.

Dan Swiertz – *UW Madison*
After earning his M.S. degree in civil engineering from the University of Wisconsin – Madison while studying with the Modified Asphalt Research Center (MARC), Mr. Swiertz was employed with MARC as a research engineer working on various projects within the Asphalt Research Consortium and in industry. His research focused on the effects of recycled asphalt on virgin binder properties as well as effects of mixture design on pavement noise and friction. Mr. Swiertz is currently co-employed with the Bitumix Solutions Laboratories in Portage, WI as the Director of Mix Design Laboratories as well as with the University of Wisconsin, Madison as a researcher. His work focuses on asphalt binder and emulsion formulation, new product development and implementation, quality control, and technical consultation. Mr. Swiertz is a registered Professional Engineer in the State of Wisconsin and holds the following WisDOT highway technician (HTCP) certifications: AGGTEC-1, HMA-IPT, HMA-TPC, and HMA-MD.

8. Other Commitments of the Research Team

Table 9. Other Commitments of the Lead Research Team

Hussain Bahia, Ph.D.		
Commitments	Percentage of Time	
	Committed	Available
Dept. of Civil, Construction, & Environmental Engineering	30%	
Pooled Fund Study (0092-14-20), TPF-5 (302) “Modified Binder (PG+) Specifications and Quality Control Criteria”	10%	
WisDOT 0092-17-04, Ends 07/2018	10%	
Modified Asphalt Research Center (MARC)	10%	
Time Available		40%

Louay Mohammad, Ph.D.		
Commitments	Percentage of Time	
	Committed	Available
–Teaching, Department of Civil and Environmental Engineering	25%	
Research	50%	
Time Available		25%

Daniel Swiertz, PE		
Commitments	Percentage of Time	
	Committed	Available
Bitumix Solutions	70%	
UW Madison Lecturer Duty (Anticipated)	5%	
WHRP 0092-17-04 (Ends 07/2018)	10%	
Time Available		15%

9. Equipment and Facilities

UW-Madison, Modified Asphalt Research Center

The Asphalt research facilities of the College of Engineering are part of the Wisconsin Structures and Materials Laboratory. The facilities are housed within the Engineering building on the main campus in Madison. The facilities total area dedicated for asphalt testing is approximately 1600 square feet. The following sections include details of equipment available.

Asphalt Binder Laboratory

The Asphalt Binder Laboratory has state-of-the-art SuperPave testing equipment to characterize asphalt binders and emulsion residue using both standard and non-standard tests. In addition, the laboratory is equipped to perform low temperature residue recoveries (evaporative recovery) for asphalt emulsion.

Asphalt Mixture Laboratory

For preparation of samples and evaluation of mixture behavior during construction the laboratory is equipped with two SuperPave Gyratory compactors. For mixture characterization the lab maintains two servo-hydraulic testing machines for performing testing according to SuperPave and mechanistic design procedures. One of the testing systems is equipped with an environmental chamber and allows measuring the low and intermediate Indirect Tension (IDT) mixture testing, repeated creep, dynamic modulus, and SCB testing.

Louisiana State University – Transportation Research Center (LTRC)

LTRC is located on the Louisiana State University (LSU) campus on Gourrier Avenue in Baton Rouge, Louisiana. The center occupies a 23,600 square-feet building, which houses a nucleus of five laboratories. The asphalt laboratory occupies 2,645 square-feet. It is capable of performing virtually all required tests on aggregates, asphalts, and mixtures. The asphalt laboratory at LTRC is equipped and staffed with state-of-the-art facilities to undertake the full range of standard ASTM/AASHTO and research type of tests on binder, aggregate, and asphalt mixtures. LTRC's asphalt laboratory is accredited by AASHTO for asphalt binder and HMA tests. The following mixture and binder testing equipment is available:

Examples of Mixture Testing Equipment

- Four Superpave Gyratory Compactors
- Cox and Sons CS 7000 Superpave Shear Tester
- Cox and Sons CS 7500 Universal Testing Machine With Environmental Chamber
- IPC UTM-25 Universal Testing Machine With Environmental Chamber and triaxial cell
- IPC Asphalt Mixture Performance Tester
- MTS Model 810 with 22,000 lbs loading capacity with triaxial cell
- MTS Model 810 with 55,000 lbs loading capacity with Environmental Chamber
- One MTS and Two Epsilon clip-on extensometers for measuring axial and radial displacement
- Two PMW Wheel Tracking Device and a Kneading Compactor
- Bending Beam Fatigue Fixture in accordance with AASHTO test method T321
- Instrotek Corelok^{TM} Vacuum Sealing System and CoreDry^{TM}
- Troxler Model 3660 Core-Reader
- Troxler Model 4730 NTO Extraction Furnace
- Two Louisiana Interlayer Shear Strength Tester (LISST) Devices,
- Louisiana Tack Coat Quality Tester (LTCQT)

Examples of Binder Testing Equipment

- Asphalt Binder Extraction and Recovery Systems
- infraTest Asphalt Analyzer (closed-loop Automatic binder extraction system)
- High Pressure Gel Permeation Chromatography (HP-GPC) - Agilent 1100
- Superpave PG Grading Equipment
- Two Antaa Paar Dynamic Shear Rheometers – Model MCR 301
- A Leica TCS SP2 Confocal Laser-Scanning Microscope
- Iatroscan system for SARA analysis

10. Technician and Laboratory Certification

The Asphalt Technologies Group Laboratory is fully AASHTO accredited as well as certified with WisDOT and the Combined State Binder Group. LTRC's asphalt laboratory is accredited by AASHTO for asphalt binder and HMA tests. Mr. Swiertz is certified with the Wisconsin Highway Technician Certification Program at the AAGTEC-1, HMA-IPT, HMA-TPC, and HMA-MD levels. UW-MARC laboratories are not AASHTO accredited, however the center maintains annual calibration of testing equipment and participates quarterly in the Combined States Group Round Robin Testing Program and also leads round robin testing of asphalt binders and mixtures for the Rocky Mountain User Producers Groups.

11. References

Crovetti, J., Castedo, W., Ainge, S., & Nguyen, C. (2012). *WHRP 09-02 Performance Evalaution of Tack Coat Materials.* Madison: Wisconsin Highway Research Program.

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Mohammad, L., Elseifi, M., Bae, A., Patel, N., Button, J., & Scherocman, J. (2012). *NCHRP Report 712 Optimization of Tack Coat for HMA Placement.* Washington, D.C.: National Cooperative Highway Research Program.

Seo, A., Sakhaeifer, M., & Wilson, B. (2017). Evaluating Tack Properties of Nontracking Tack Coats Through Dynamic Shear Rheometer. *Transportation Research Board*, Presentation.

Wilson, B., Seo, A., & Sakhaeifar, M. (2016). *Performance Evaluation and Specification of Trackless Tack.* Austin: Texas Department of Transportation.

Kim, R. et al, "Performance-Related Specifications for Emulsified Asphalt Binders Used in Preservation Surface Treatments," NCHRP Report 837, Washington, D.C.: National Cooperative Highway Research Program.

12. Cooperative Features

LOUISIANA TRANSPORTATION RESEARCH CENTER

Research, Technology Transfer, Education & Training

DOTD
LOUISIANA DEPARTMENT OF TRANSPORTATION & DEVELOPMENT

January 18, 2017

Dr. Hussain Bahia
Department of Civil, Construction, and Environmental Engineering
University of Wisconsin-Madison
3350 Engr. Hall. 1415 Engineering Dr.,
Madison, WI, 53706

RE: Wisconsin Highway Research Program: Investigation of Tack Coat Materials on Tracking Performance

Dear Dr. Bahia,

We are pleased to be part of the University of Wisconsin-Madison (UW-M) team on the RFP of the referenced project. To the best of our knowledge there are no conflicts of interest in participating on this research study. If UW-M is awarded this contract, LTRC will provide the time, personnel, and expertise necessary to accomplish the objectives of the project as outlined in the proposal.

If you need additional clarification, please contact me at (225) 767-9126, e-mail Louaym@Lsu.Edu.

Sincerely,

Louay Mohammad

Louay N. Mohammad, Ph.D.
Professor

4101 Gourrier Avenue • Baton Rouge, Louisiana 70808 • (225) 767-9131 phone • (225) 767-9108 fax
Sponsored jointly by the Louisiana Department of Transportation and Development and Louisiana State University

Asphalt Technologies
GROUP
A Division of H.G. Meigs

January 17, 2017

Hussain Bahia, PhD
3350 Engineering Hall
1415 Engineering Drive
Madison, WI 53706

RE: Tack Coat Study

Dear Dr. Bahia:

Asphalt Technologies Group is pleased to support the University of Wisconsin, Madison team, with technical support and laboratory testing services to complete the required testing for the tack coat research project.

If the UW is awarded the contract, Asphalt Technologies Group will prepare standard tack coat materials on a laboratory mill using a consistent base stock source. We will also perform asphalt emulsion testing using standardized testing procedures.

Asphalt Technologies Group is a division of Henry G. Meigs, LLC. To the best of my knowledge there are no conflicts of interest with our company participating on this important research project. Thank you for including Asphalt Technologies Group on your team. If you require any additional information, please do not hesitate to contact me. We look forward to working with you.

Sincerely,

Diane R Franseen

Diane Franseen
Director – Binder and Emulsion Laboratories
Asphalt Technologies Group