New Brunswick Field Study on Optimization of Tack Coat Rate to Enhance Interface Bonding of Asphalt Layers

Sina Varamini, Ph.D, P.Eng.
Research and Development Manager
McAsphalt Industries Ltd.

Alain Cormier, P.Eng.
Technical Sales and Marketing
McAsphalt Industries Ltd.

Matthew Sweezie, P.Eng.
Paving Engineer
New Brunswick Department of Transportation and Infrastructure

Ryan Barclay, C.E.T
Senior Regional Asphalt Technician
New Brunswick Department of Transportation and Infrastructure

Anton S. Kucharek, P.Eng. C.Chem.
Technical Director
McAsphalt Industries Ltd.

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ABSTRACT

Tack coats are thin applications of emulsified asphalt used to create an adhesive bond between asphalt layers, to allow for the creation of a monolithic structure as per pavement design requirements. The result is a “non-slip” structure comprised of fully-bonded pavement layers to distribute the traffic loads at an acceptable stress level to the subgrade. However, fully-bonded conditions may not necessarily be achieved during the pavement construction if the application rates are not optimized.

This paper presents results of a 2018 field study conducted on a four-lane highway in the Province of New Brunswick. For this study, the maximum bond strength was determined by considering four tack coat spray rates in combination with two surface textures: milled surface and new asphalt mix.

A section with no tack coat was also evaluated as a control section. Cores were subsequently collected following construction operations in order to determine the initial interlayer shear bond strength. An innovative “non-tracking” emulsion was used for this study as a tack coat for all the sections. Findings from this project will be used to provide recommendations and guidelines for optimum application rate, as well as construction best practices. This paper provides a summary of the field experiment and observations.

1. INTRODUCTION

Tack coats are thin applications of emulsified asphalt used to create an adhesive bond between asphalt layers, which forms a monolithic structure as per pavement design requirements. The result is "non-slip" or fully-bonded pavement layers that distribute the traffic loads at an acceptable stress level to the subgrade. However, fully-bonded conditions may not necessarily be achieved during the pavement construction if the application rates are not optimized and/or the effectiveness of tack coat material is not quantified.

The effectiveness of the tack coat depends on the type of the product, the surface preparation, as well as the spray rates. There are three main types of tack coats, which include: hot asphalt cement, emulsified asphalt cement (emulsions), or cutback asphalt cement (Gierhart & Johnson, 2018). Emulsions are the most commonly used tack coat products, which are either anionic or cationic depending on the charge surrounding the emulsified asphalt particles. The charge-attraction between the emulsion particles and the aggregate is mainly related to the mineralogy of the aggregate. This aspect must be considered prior to the selection of tack coat product to maximize bonding between the layers. Aside from tack coat and aggregate charge compatibility, the setting (curing) rate of the tack coat emulsion becomes important factor in the selection process due to its association to limiting interruptions in paving operations. Even when tack coats are allowed to set properly, construction vehicles and equipment could still pick up the tack on their tires and leave the existing roadway with little or no tack in the wheelpaths. Tire pick-up or tracking can be related to paving best practices or the cleanliness of the road surface being overlaid, as well as the properties of the tack itself. It is therefore recommended to use a tack coat product that sets in a timely fashion and exhibits "non-tracking" properties.

1.1. Research Scope and Objectives

This research project was carried out in partnership between McAsphalt Industries and the New Brunswick Department of Transportation and Infrastructure to evaluate the optimum tack application rate by considering four tack coat spray rates in combination with two surface textures: milled surface and new asphalt mix. Sections with no tack were also part of the study for both surface types. Due to budget limitations, only one "non-tracking" emulsion was used for this study as a tack coat for all the sections. Findings from this collaborative project provided recommendations and guidelines for optimal application rates, and ultimately could provide means in lowering risks and costs associated with premature failures due to improper bonding of pavement layers.

2. FIELD STUDY

Figure 2-1 presents a plan view of five test sections constructed on Highway 15, east of the City of Moncton in New Brunswick. All test sections were located on the westbound driving lane of the four-lane highway. Each test section was a total of 200 meters in length and 3.7 meters in width.

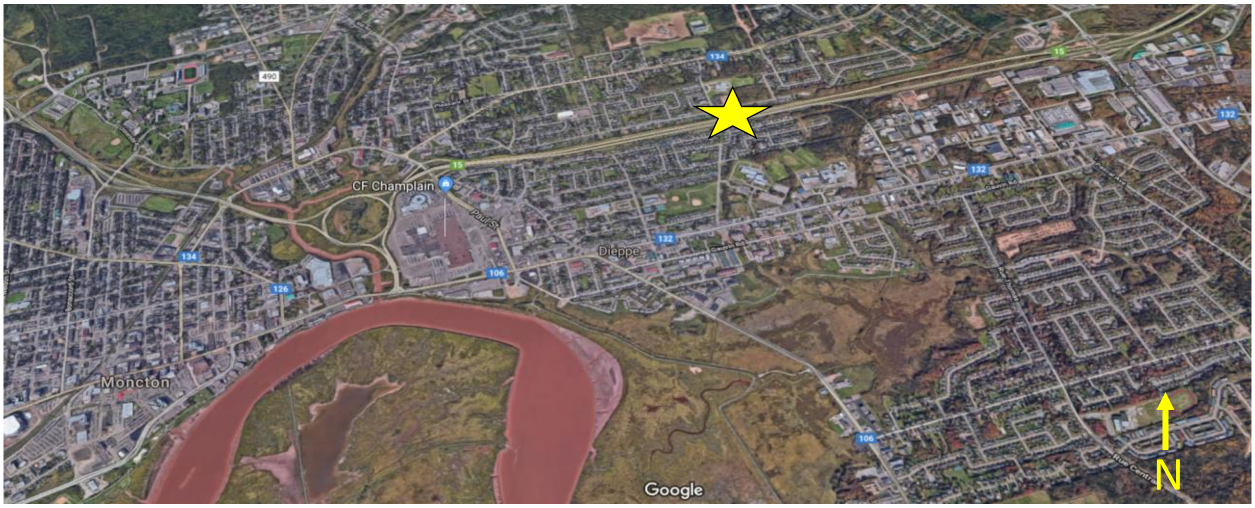

Figure 2-1 Location of Field Study Marked Google Map – Located on a Section of Highway 15, Approximately 1 km East of Moncton, New Brunswick

Table 2-1 presents the matrix used to complete the field experiment and laydown operations, which utilised conventional paving equipment and a computerized tack coat distributor truck. Two types of pavement surfaces and one tack coat material were evaluated in this study. The tack coat was sprayed at four rates as listed in Table 2-1. Also, a section with no tack coat was constructed as a control section.

Table 2-1 Variables Considered in The Study

Variables	Description
Pavement Surface	1. New HMA 2. Milled HMA
Non-Tracking Tack Coat Spray Rate	1. 0.20 L/m^2 (Residual AC 0.08 L/m^2) 2. 0.40 L/m^2 (Residual AC 0.16 L/m^2) 3. 0.60 L/m^2 (Residual AC 0.23 L/m^2) 4. 0.80 L/m^2 (Residual AC 0.31 L/m^2)

Table 2-2 Physical Properties of Non-Tracking Emulsion Used in The Study (undiluted results)

Test	Typical Data
SF Viscosity, 25°C, SFs	28
Sieve Test, 850 µm, %	0.02
Residue by Distillation, 260°C, %	60.5
Oil Portion of Distillate, %	0.0
Particle Charge	Negative
Penetration on Asphalt Residue, 25°C, dmm	35
Ash Content, %	0.15

To minimize variations in the study, the following conditions were kept consistent throughout construction of the test sections.

- Length of test sections
- Pavement surface and ambient temperature
- Type of the distributor truck.
- Spray bar height, truck speed, nozzle configuration, and application pressure.
- Milling operations / equipment and sweeping effort after milling.

Since all experiments made use of full-scale test lanes, a description of the construction process and the test variables in the field experiment is presented in the following section.

2.1. Surface Characterization

All test sections contained a similarly aged asphalt surface which was milled prior to overlay. Extra care was taken to ensure all debris generated from milling was swept and the final surface was cleaned as shown in Figure 2-2 prior to application of tack coat.

The sand patch test, ASTM E965-15 (ASTM International, 2015) was performed to characterize the texture depth or so called "macro-texture" of the two types of surfaces being overlaid: milled vs new HMA. The test was performed by the University of New Brunswick at three different locations within each test section. For this test, a measured quantity of sand was poured on the surface and spread in a circular patch, using a rubber disk tool, until the sand was level with the peaks of the surface, after which the diameter of the patch was recorded. The correlation between the sand patch diameter and Mean Texture Depth (MTD) is inversely proportional. A rougher surface (milled) would have a small and inconsistent diameter, whereas, a slightly smoother surface (newly paved HMA) would have a more consistent and larger diameter. The MTD on milled surface was also considered as a uniformity factor.

Figure 2-2 Milled Texture Prior to Application of Tack Coat (Left) and Measurement of Texture Depth Using the Sand Patch Test (Right)

2.2. Tack Coat Application and Verification

Prior to the study, calibration trials were performed with an Etnyre computerized distributor truck (Figure 2-3) to ensure the selected application rates could be achieved. Proper size nozzles were then chosen to coincide with the spray rates specified in the various test sections (0.2 to 0.8 L/m^2) in order to achieve a uniform application of the tack coat. In all, two nozzle types were required. The total width of the spray bar was extended to accommodate full single-lane coverage. During the tack coat spraying, the truck speed was kept consistent in all test sections. The distributor truck was equipped with a heated tank for maintaining the tack coat at a targeted application temperature which was verified at the job site. The tack coat was applied in the diluted state (60:40 – emulsion to water).

Figure 2-3 Etnyre Distributor Truck Used for the Study

The procedure outlined in the ASTM D 2995 (ASTM International, 2014) test method was followed to verify application rates for each section. For this test method, rectangular (380 mm by 480 mm) absorbent pads were pre- weighed and then attached to the pavement surface using a two-sided adhesive tape prior to tack coat application. The layout of the pads is illustrated in Figure 2-4. Three pads were aligned in the transverse and longitudinal directions relative to the test lane, while spaced enough for the wheels of the distributer truck to pass in between the transverse pads during the spray process. After the tack application was completed, the pads were allowed to remain in position for at least an hour to ensure all water in the emulsion had evaporated. All pads were then collected from the road sections and sent to the University of New Brunswick pavement laboratory to record the final weights and to calculate the residual rate of asphalt binder.

Figure 2-4 Layout of Absorbent Pads Used in Verification of Tack Coat Applications

2.3. Specimen Coring

Cores were subsequently collected following construction operations in order to evaluate the initial interlayer shear bond strength explained in section 2.4 of this paper. Six specimens were obtained from each test section; two from the inner wheelpath, two from the outer wheelpath and two from the center of the westbound driving lane as illustrated in Figure 2-5. To minimize vibration and to maintain consistency of the core specimens, coring was completed using a machine equipped with a pedestal and support column as shown in Figure 2-6. Water was used during the coring operation to reduce friction and any effect of localized heat generated by coring on the tack coat layer. The core barrel was driven to the bottommost layer in order to remove the core undisturbed and to avoid any pre-stressing. Because water was used during coring, specimens were allowed to dry at 25°C for a minimum of two days. Specimens were conditioned at 25°C in an environmental chamber for minimum of two hours prior to interface shear strength testing.

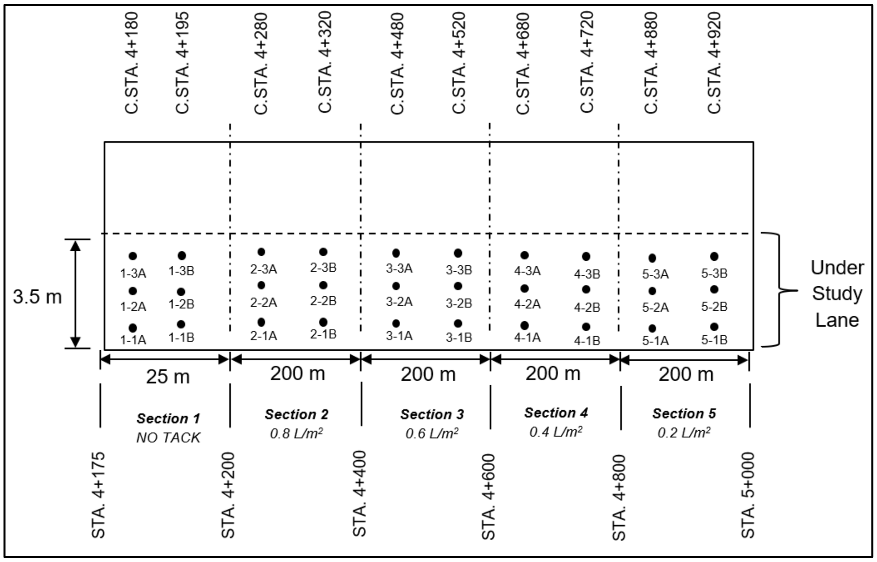

Figure 2-5 Coring Layout

Figure 2-6 Coring Operation Using Pedestal and Support Column (Left), Interfaces Under Study Shown on a 100-mm Diameter Core: Interface Between Newly Paved Surface Course and and Base Course Mix (Marked as "A") and Interface Between Newly Paved Base Course and Milled Surface (Marked as "B") (Right)

2.4. Evaluation of Interlayer Shear Strength

The initial interlayer shear strength (ISS) was evaluated in a laboratory-controlled environment by using the apparatus shown in Figure 2-7 and testing was performed at a temperature of 25℃. The shear strength was determined for two interfaces: between the newly paved surface and base course mix, and between newly paved base course and milled surface. Shear load was applied in a monotonic mode at the rate of 50 mm/min to one layer, while the other layer was held stationary. The shear loading was aligned and centered above the interface and applied using InstroTek© equipment (Figure 2-7), while the rate of shearing displacement was recorded using a linear variable differential transducer (LVDT). Figure 2-8 illustrates the shear load-displacement curve. The study used specimens with diameters of 100 mm and variable heights depending on the profile of the road sections and the average ISS was calculated using Equation 1.

$$ISS = \frac{P_{ULT}}{A} \qquad \textbf{Equation 1}$$

where:

$ISS =$ Interlayer shear strength (Pa)
$P_{ULT} =$ Ultimate load applied to specimen (N)
$A =$ Cross-sectional area of test specimen (m^2)

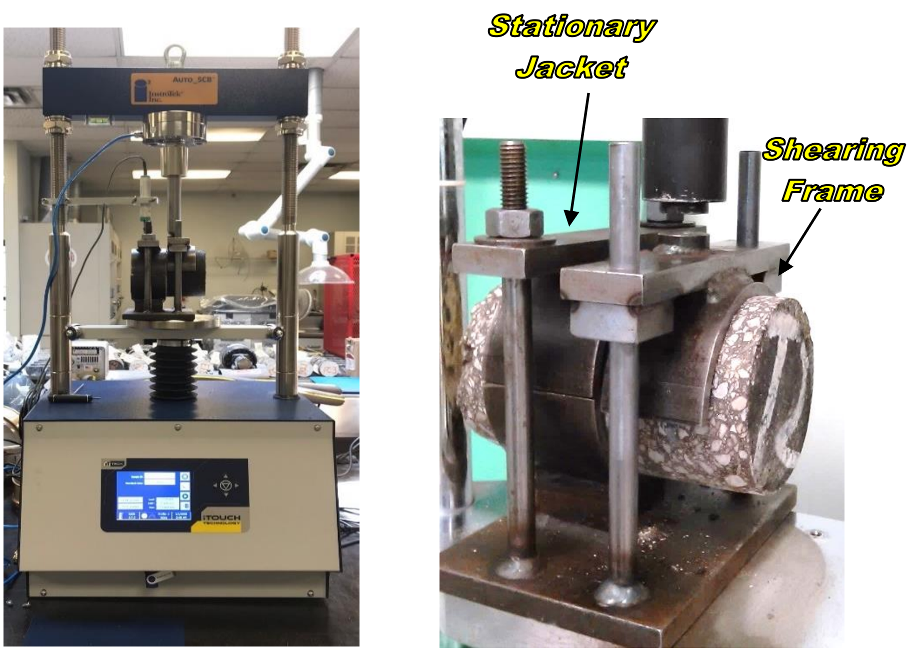

Figure 2-7 InstroTek© Testing Frame (Right) and Interlayer Shear Strenght (ISS) Apparatus (Left)

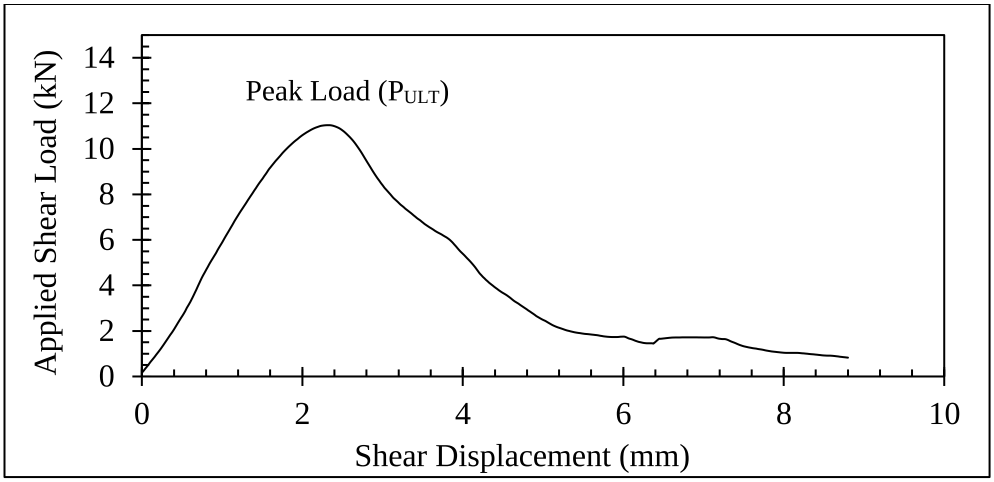

Figure 2-8 Typical Shear Load-Displacement Curve

3. RESULTS AND DISCUSSIONS

For each combination of application rate and surface texture, six specimens were tested for interlayer shear strength (ISS). Figure 3-1 present the mean ISS results for all application rate and surface texture combinations, while the error bars represent one standard deviation. The coefficient of variation (COV) for all combinations are presented in Table 3-1. All tests were performed at a temperature of 25°C. Results of tack coat rate verification and sand patch tests are shown as well in Figure 3-2 and Figure 3-3, respectively.

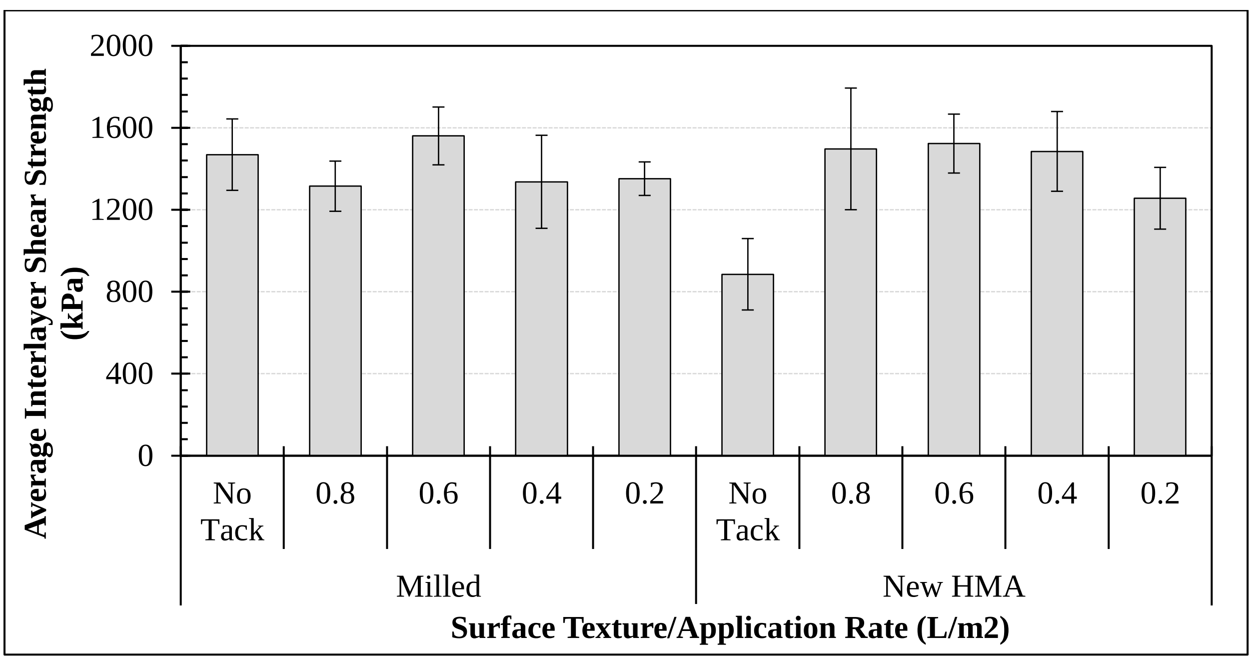

Figure 3-1 Interlayer Shear Strenght (ISS) Results

Table 3-1 Analysis of Optimum Tack Coat Application Rate

Application Rate (L/m^2)	Milled Surface Average ISS (kPa)	Milled Surface COV (%)	New HMA Surface Average ISS (kPa)	New HMA Surface COV (%)
No Tack	1469.1	8.70%	885.4	10.2%
0.80	1315.2	10.0%	1497.2	13.8%
0.60	1560.4	16.1%	1523.1	10.7%
0.40	1336.6	5.81%	1484.9	17.3%
0.20	1351.8	12.4%	1256.3	10.0%

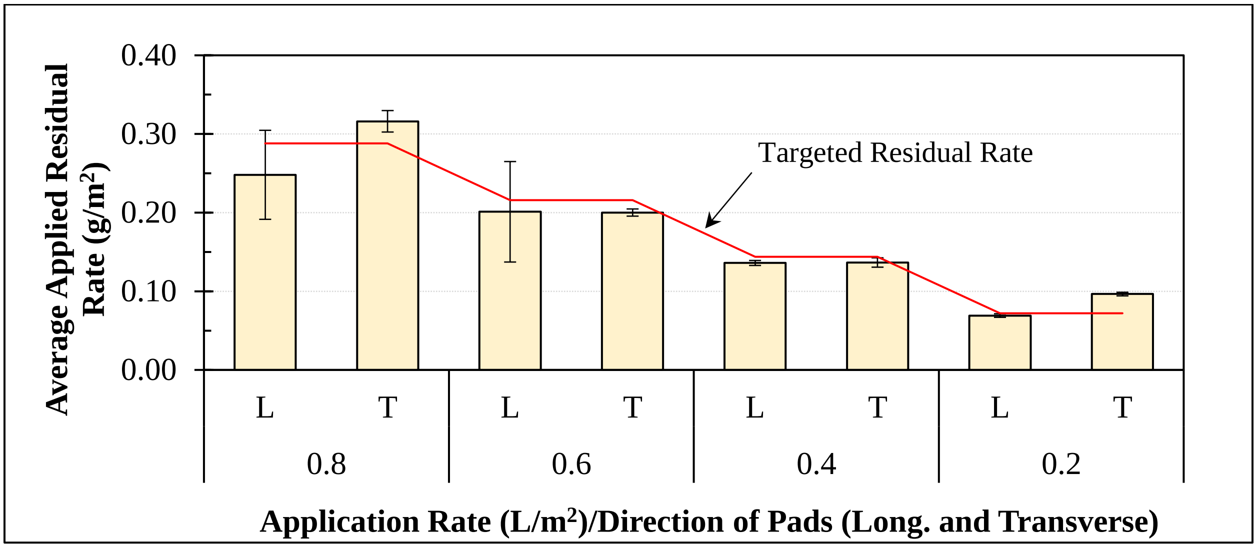

Figure 3-2 Results of ASTM D 2995 Field Verification of Application Rates

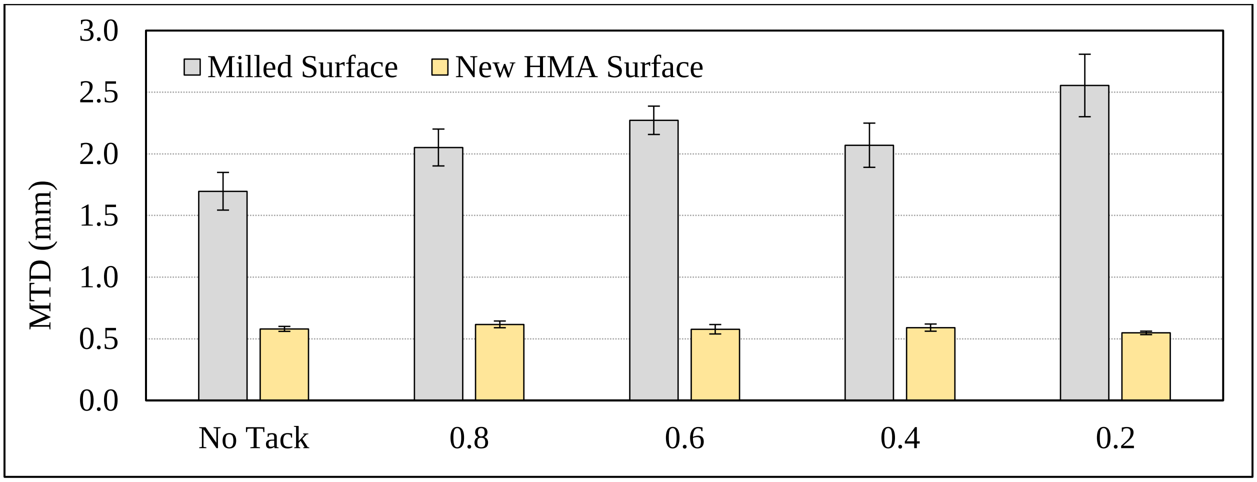

Figure 3-3 Mean Texture Depth (MTD) Measure Using Sand Patch Test

Test results listed in Table 3-1 show high consistency in ISS, except for the 0.4 L/m^2 application rate on newly paved asphalt surface due to COVs relatively higher than 15%. Based on the relationship between ISS and tack coat application rate, shown in Figure 3-1, highest shear strength was achieved after using an application of 0.6 L/m^2 of diluted 60:40 “trackless type” tack coat on a newly paved HMA surface texture. Similarly, the same 0.6 L/m^2 application rate resulted in highest shear strength when tack coat was applied on the milled surface.

The average ISS for 0.6 L/m^2 rate on new HMA surface was found not significantly different from 0.4 L/m^2 and 0.8 L/m^2 application rates, as shown in Figure 3-1, but it was found to significantly increase the shear strength by 70% when compared to the average shear strength measured for no tack section. A very similar trend was observed for the milled surface within other application rates, except for the no tack on the milled surface, which resulted in relatively stronger bond compared to other tack coat applications. This could be attributed to the aggregate interlock within the non-tacked specimen/cores affecting the results when tested in the shearing device.

Figure 3-2 presents the results of verifying tack coat application rates using ASTM D 2995. For this test, absorbent pads were attached to the pavement surface (only over the milled surface) in transverse and longitudinal directions. The results of this test show that consistent applications rates of 0.4 and 0.6 L/m^2 were achieved for the milled texture (Figure 3-2) depth in both directions with errors less than the 10% limit specified by ASTM D 2995.

However, switching to application rates of 0.8 and 0.2 L/m^2 seemed to create inconsistency in directional coverage on the milled sections. It is noted that both directional application rates are slightly different than the target residual rate; however, the measured rates met the objectives of the test matrix to simulate low, medium, and high levels of tack coat applications. Furthermore, Figure 3-3 illustrates that milled surface was relatively rougher than newly paved surface with more inconsistency which may be related to the milling operations.

4. **CONCLUSIONS**

This paper presents results of a 2018 field study conducted on a four-lane highway in the Province of New Brunswick. For this study, the optimal bond strength was determined by considering four tack coat spray rates in combination with two surface textures: milled surface and new asphalt mix. A section with no tack coat was also evaluated as a control section. Cores were subsequently collected following construction operations in order to determine the initial interlayer shear bond strength. Following conclusions can be drawn:

Based on the relationship between ISS and tack coat application rate, highest shear strength was achieved after using an application of 0.6 L/m^2 of diluted 60:40 “trackless type” tack coat on a newly paved HMA surface texture. The same application rate used on a milled surface was also resulted in the highest shear strength.

It should be mentioned that the current application rate in the Province of New Brunswick is 0.25 to 0.35 L/m^2 of 60:40 diluted trackless type tack, which as determined in this study, could be increased to achieve better performance.

Higher spray rates of 0.6 and 0.8 L/m^2 of diluted emulsion were shown to result in longer curing times. It should be mentioned that the test sections in this study were closed overnight, and traffic was not allowed on the tack until the next day. This was done in order to more closely mimic laboratory conditions and to get the most accurate data possible. However, such restrictions may not be possible during day-to-day paving operations and could result in increased chance of tracking and pick-up issues by contractors' equipment and haul trucks. To achieve a balance between strength and practical field applications, the optimal application rate of 0.6 L/m^2 for example for newly paved surface could be applied in a concentrate state. This would minimize curing time, while providing higher interlayer shear bond strength.

Currently tack coat application rates across Canada vary quite significantly. The goal is to determine which rate is the optimal one with regards to on-site practicality, curing time, shear strength, life cycle costing and overall performance of the road.

5. ACKNOWLEDGEMENT

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