Examining an Accelerated Wet Track Abrasion and Schulze-Breuer and Ruck Test for Micro-surfacing Mix Design

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ABSTRACT

Currently, the International Slurry Surfacing Association (ISSA) guideline is the most widely used standard to evaluate micro-surfacing mix designs. The ISSA A143 guideline includes two time-consuming tests to examine the moisture susceptibility of a micro-surfacing system, specifically, the Wet Track Abrasion Test (WTAT) and the Schulze-Breuer & Ruck (SB & R) test. Including sample preparation and a required 6-day soak for both of these tests, a mix design requires at least 9 full days to complete. This turnaround time can be problematic during the construction season if, after 9 days, an aggregate is rejected.

An accelerated procedure for WTAT and SB & R has been proposed in which samples are soaked at elevated temperature for 3 hours rather than at 25°C for 6 days. However, testing at the McAsphalt Industries Ltd. Western Research Centre showed significant differences between the conventional and accelerated conditioning for the WTAT and SB & R test. Highway sections observed after one-year in-service indicated that the WTAT results generally correlated with field performance while the SB & R test as currently specified by the ISSA may be a more useful predictor of in-service performance if modifications are made to the test itself or the classification system.

RÉSUMÉ

À l'heure actuelle, la directive de l'International Slurry Surfacing Association (ISSA) est la norme la plus largement utilisée pour évaluer les conceptions de mélanges de micro-surfaces. La ligne directrice A143 de l'AISS comprend deux essais chronophages pour examiner la sensibilité à l'humidité d'un système de micro-surfaçage, en particulier le test d'abrasion sur piste mouillée (WTAT) et le test Schulze-Breuer & Ruck (SB & R). En tenant compte de la préparation des échantillons et d'un trempage de 6 jours requis pour ces deux tests, la conception d'un mélange nécessite au moins 9 jours complets. Ce délai peut être problématique pendant la saison de construction si, au bout de 9 jours, un granulat est rejeté.

Une procédure accélérée pour WTAT et SB & R a été proposée dans laquelle les échantillons sont trempés à température élevée pendant 3 heures plutôt qu'à 25°C pendant 6 jours. Cependant, les tests effectués au Western Research Center de McAsphalt Industries Ltd. ont révélé des différences significatives entre le conditionnement conventionnel et le traitement accéléré pour le test WTAT et le test SB & R. Les tronçons routiers observés après un an de service ont indiqué que les résultats du test WTAT étaient généralement corrélés aux performances sur le terrain, tandis que le test SB & R, tel qu'il est actuellement spécifié par l'AISS pourrait être un prédicteur plus utile de la performance en service si des modifications sont apportées au test lui-même ou au système de classification.

1.0 INTRODUCTION

1.1 Current Micro-surfacing Mix Design Practice

The International Slurry Surfacing Association Recommended Performance Guidelines for Micro-surfacing (ISSA A143) is one of the most widely-used guidelines for designing micro-surfacing systems. It includes a series of technical bulletins providing instruction on mix development, determination of compatibility of components, and cohesion and performance testing of the cured mix. The complete suite of tests and specifications is presented in Table 1. Not all tests need to be completed for each design. The procedures chosen to develop and test the mix are determined by agencies or laboratories based on experience with micro-surfacing mixes and/or performance of specific mixes previously used in the field.

Table 1. ISSA A143 Tests and Specifications [1]

Test	ISSA TB No.	Specification
Mix Time at 25 °C	TB113	Controllable to ≥ 120 seconds
Wet Cohesion 30 minutes (set) 60 minutes (traffic)	TB 139	 ≥ 12 kg-cm ≥ 20 kg-cm
Wet Stripping	TB114	≥ 90%
Wet Track Abrasion Loss 1-hour soak at 25 °C 6-day soak at 25 °C	TB100	 ≤ 538 g/m^2 ≤ 807 g/m^2
Lateral Displacement Specific Gravity	TB147	≤ 5% ≤ 2.10
Excess Asphalt by LWT	TB109	≤ 538 g/m^2
Classification Compatibility	TB144	≥ 11 points (AAA, BAA)

Note: ISSA is the International Slurry Surfacing Association, TB is Technical Bulletin, and LWT is Loaded Wheel Test.

The Wet Track Abrasion Test (WTAT) is completed to determine potential susceptibility to long-term moisture damage but it is also used to determine the minimum amount of asphalt required in the design. The test is also completed at a 1-hour conditioning to look at shorter term ravelling potential. However, it is generally accepted that the 6-day conditioned wet track is a more valuable measure that can be examined in conjunction with the excess asphalt by the Loaded Wheel Test (LWT) to determine the optimum amount of asphalt emulsion that should be included in the mix. The 6-day conditioned wet track is included in most other guidelines used worldwide.

The Schulze-Breuer and Ruck (SB & R) test is included in few guidelines other than ISSA. Its purpose is to be a final check on the compatibility of mix components including aggregate fines, asphalt cement, and reactive filler. It is one of four ISSA tests that examines the compatibility of components. The SB & R test is a difficult test to put into practice for a few reasons including: (1) the long timeframe to complete – particularly since other compatibility tests would have already identified if there were problems with the mix, and (2) the validity of parts of the test are suspect [2]. This may be why the test is not in widespread use, however, it is completed by some laboratories to provide further information about the behaviour of the mix and assist in choosing the optimum design.

1.2 Problem Statement and Previous Investigation

As noted in Table 1, there are two tests that require a 6-day conditioning period. Considering the time required to complete aggregate preparation, make the mixes and then cast, cure and condition all the samples, a micro-surfacing design takes at least 9 days to complete. Aside from these two tests most of the design work can be completed within a couple of days, therefore, the obstacle toward more timely design completion during the busy construction season is the extended conditioning time.

To shorten the time required to complete a micro-surfacing design, Zhai and Rosales [3] investigated a method to accelerate both the WTAT and the SB & R test. Similar to the conditioning protocol used for evaluating moisture susceptibility of asphalt mixtures (AASHTO T 283), they examined soaking samples at 60°C for a shortened amount of time rather than the 25°C water bath for 6 days. Their findings suggested that a 3-hour conditioning period at 60°C followed by 1-hour soak at 25°C could correlate well with results obtained by the conventional 6-day soak at 25°C for the WTAT. Similarly, they concluded that there was no significant difference in results of SB & R samples conditioned for 3 hours at 60°C from those soaked for 6 days at 25°C. They also noted no significant difference in these results by using Styrene-Butadiene Rubber (SBR) or Styrene-Butadiene-Styrene (SBS) polymer modified emulsion, or by varying the aggregate gradation.

1.3 Scope of Current Investigation

The McAsphalt Industries Western Research Centre (WRC) designs between 30 to 40 micro-surfacing and slurry seal systems each construction season for customers in Western Canada and Northern United States. At the peak of season, the capacity of one laboratory technician with one set of equipment can be exceeded by the demands of contractors experiencing unforeseen changes in their construction schedules, aggregate sources or other demands common to the industry. It is desirable to have a method of accelerating designs to meet schedules when required or to complete quick and reliable checks on suitability of raw materials to ensure they can meet requirements for acceptable designs. During the 2017 construction season, the WRC completed the accelerated testing described by Zhai and Rosales [3] on wet track and SB & R samples alongside those completed by the conventional method for selected designs used by contractors in the field. The purpose was to determine if the accelerated method would provide comparable results to those obtained by conditioning in the conventional way based on the raw materials and methods used in this particular laboratory.

1.4 Overview of the Tests

The WTAT is used to determine the minimum amount of asphalt emulsion required in the mix and the abrasion resistance under wet conditions. It is considered one of the most important mix performance procedures as it tests the compatibility of all components of the cured mix under moisture conditions. The test is designed to simulate a vehicle cornering and braking in wet conditions. The WTAT is completed at 1-hour and 6-day time intervals to provide an indication of early ravelling potential as well as longer term abrasion resistance. A mix is made using aggregate passing the 4.75 mm (No. 4) sieve and poured into a circular mold. It is air cured and then soaked at 25°C for 1 hour or 6 days. It is then abraded with a weighted rubber hose fitted to a planetary mixer for 300 cycles. The abrasion loss is calculated as the maximum weight loss in grams per square metre. It is suggested that 538 and 807 g/m^2 abrasion loss for the 1-hour and 6-day wet track, respectively, are the threshold values that correlate to the risk of ravelling.

The SB & R procedure was developed to detect potential for long-term moisture damage related to incompatibilities between the aggregate, mineral filler and asphalt binder. The test is performed by utilizing a specified gradation below the 2.00 mm (No.10) sieve and pressed into pills approximately 30 mm in diameter and height. The pills are soaked in 25°C water for 6 days and then wet tumbled in a Schulze-Breuer Test machine for 3,600 cycles. Afterwards, the pills are immersed in boiling water for 30 minutes. Test data obtained is used to calculate absorption, abrasion, adhesion, and integrity, which are then translated into a classification system shown in Table 2.

Table 2. Suggested Classification System for SB & R Test as per ISSA TB 144 [4]

Grade	Point Rating	Abrasion Loss (g)	Integrity (% Retained)	Adhesion (% Coated)
A (Best)	4	≤ 0.7	90 - 100	90 -100
B (Pass)	3	0.71 - 1.0	75 - 89	75 -89
C (Marginal)	2	1.01 - 1.3	50 - 74	50 -74
D (Fail)	1	1.31 - 2.0	10 - 49	10 -49
0 (Fail)	0	≥ 2.1	≤ 9	≤ 9

Note: ISSA is the International Slurry Surfacing Association, SB & R is the Schulze-Breuer and Ruck test, and TB is Technical Bulletin.

2.0 MATERIALS AND METHODS

2.1 Materials and Job Mix Formulae

A Cationic Quick Setting polymer modified (CQS-1HP) emulsion was prepared by laboratory colloid mill. The typical results for this emulsion are shown in Table 3. The emulsifier content varied for each aggregate as dictated by the mix time requirement.

Seven different aggregate sources were selected for this work to provide robust results from which to draw conclusions. Gradations of each aggregate used are provided in Table 4. Sieve analyses were conducted in accordance with ASTM C136 and C117 to ensure aggregate met the gradation requirements as either ISSA Type II or Type III material [5, 6]. The Sand Equivalent Value (AASHTO T 176-08) was determined for each aggregate to ensure swelling clays that may affecting bonding were minimal [7]. The Methylene Blue Value, not a specification item, is an indication of aggregate reactivity and can therefore, be important for the design work [8].

The testing was conducted at the McAsphalt Western Research facility by one operator. Mixes were determined by the procedure described in ISSA Technical Bulletin No. 113 [9]. All designs used 1 percent of Type I Portland cement. This amount of mineral filler provided the mixes with good consistency, as well as break and cure characteristics. Various percentages of tap water and CQS-1HP asphalt emulsion with different concentrations of emulsifier were used to obtain a smooth mix that would resist breaking for at least 120 seconds. ISSA Technical Bulletin No. 139, the cohesion test, was used as a guideline to ensure all system components were present in an appropriate ratio and all systems achieved the requirements of quick-set and quick-traffic defined as the re-opening to traffic within one hour [10].

Table 3. Typical Results for CQS-1HP Emulsion

Test	Test Value	Specification	Standard
Saybolt-Furol Viscosity at 25°C (SFS)	28.5	20 - 100	ASTM D 7496
Sieve Test (% by mass)	0.04	< 1	ASTM D 244
Particle Charge (positive or negative)	Positive	Positive	ASTM D 244
Residue by Distillation at 205°C (% by mass)	64.3	> 62	ASTM D 6997
Oil Portion of Distillate (% volume/mass)	trace	< 5.0	ASTM D 6997
Tests on Residue			
Penetration at 25°C (dmm)	77	40 - 90	ASTM D 5
Softening Point by R&B (°C)	63	> 57	ASTM D 36
Kinematic Viscosity, 135°C (mm^2/s)	1450	> 650	ASTM D 2170

Note: CQS-1HP is cationic quick setting polymer modified (CQS-1HP) emulsion, ASTM is ASTM International, and R&B is Ring and Ball.

Table 4. Aggregate Gradations

Sieve Size (mm)	Passing (%)							Specification	
	A III	B III	C III	D III	E III	F II	G II	ISSA Type II	ISSA Type III
9.5	100	100	100	100	100	100	100	100	100
4.75	74.7	81.8	77.2	80.9	83	92.9	96.2	90 - 100	70 - 90
2.36	51.8	55.2	52.8	48.4	56.2	64.7	76.2	65 - 90	45 - 70
1.18	36.0	38.4	36.3	31.1	39.1	45.5	55.6	45 -70	28 - 50
0.6	25.3	26.9	25.1	20.9	27.3	29.9	35.6	30 - 50	19 - 34
0.3	17.6	18.7	17.3	14.9	20.2	18.5	22.9	18 - 30	12 - 25
0.15	12.2	13.0	11.9	10.1	14.4	10.5	13.3	10 - 21	7 - 18
0.075	8.5	9.1	8.2	6.9	10.3	6.7	7.7	5 - 15	5 - 15
Sand Equivalency	75	72	70	84	64	66	69	≥ 65%	≥ 65%
Methylene Blue Value	1	0.5	0.5	0.5	0.5	1	0.5	≤ 7	≤ 7

Note: ISSA is The International Slurry Surfacing Association.

All the chosen mixes were compliant with the ISSA A143 specifications shown in Table 1 except Classification Compatibility by SB & R test did not meet ISSA's suggested guideline. Details of the job mixes for each aggregate are shown in Table 5.

Table 5. Job Mix Formulae

Design Component (% by weight of aggregate)	A III	B III	C III	D III	E III	F II	G II
Aggregate	100	100	100	100	100	100	100
Portland Cement	1	1	1	1	1	1	1
Water	8	9	8	8	8	8	8
Emulsion	12	11	12.5	12	11	12	11

2.2 Wet Track Abrasion Test

Two wet track abrasion samples were prepared according to ISSA Technical Bulletin No.100 for each of the job mix formulae [11]. Aggregate passing a 4.75 mm sieve was blending with the selected ratios of cement, water and emulsion to form a slurry which was poured into a 279.4 mm diameter and 6.35 mm deep round mold placed on roofing felt. Excess slurry was careful removed to provide a level surface and when set the mold was removed and the sample cured to constant weight in a 60°C oven. The dried sample was allowed to cool before being weighed and then placed in a 25°C water bath for 6 days. At the conclusion of the conditioning period the sample was removed from the water bath, clamped into the round aluminum pan and again covered with 25°C water. The pan was placed on the platform of the Hobart A-120 planetary mixer fitted with a weighted (2.3 kg) rubber hose abrasion head as shown in Figure 1. The sample was abraded for 300 cycles before being removed and rinsed free of debris. After drying to a constant weight, the samples were re-weighed and wear value calculated by deducting the final weight from the initial weight and applying the correction factor for the Hobart A-120. The experimental accelerated sample was soaked for 3 hours in a 60°C bath, followed by 1 hour in a 25°C bath, and then tested in a similar manner as the conventional sample.

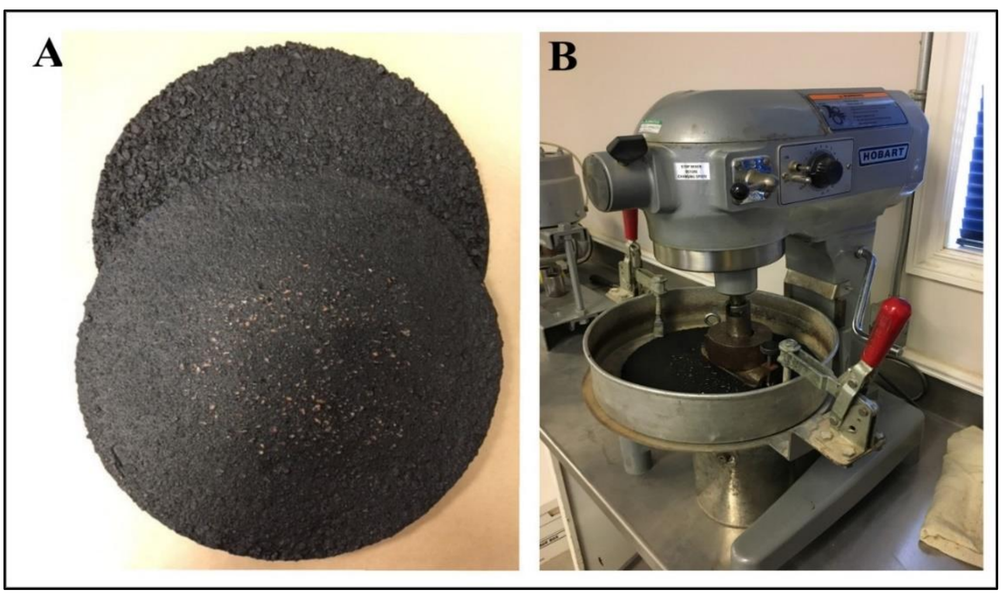


Figure 1. (A) Abraded Wet Track Sample with Untested Sample in the Background and (B) Sample Ready to be Tested on Hobart A-120 Wet Track Abrasion Tester

2.3 Schulze-Breuer and Ruck Test

The SB & R samples were prepared according to ISSA Technical Bulletin No. 144 by first re-grading aggregate such that 35 percent passed the No.10 sieve, 25 percent passed the No. 30 sieve, 22 percent passed the No.50 sieve, and 18 percent passed the No. 200 sieve [12]. Mixes were made using 200 g of aggregate, 1 percent cement, 9 percent water, and 13 percent emulsion (equating to 8.359 percent residual asphalt). The materials were mixed until cured after being dried to a constant weight and then pressed into 40 g pills using Schulze-Breuer pill molds and a 2,000 lb constant force pneumatic pill press (Figure 2). The pills were weighed and one set of four was placed in a 25°C water bath for six days while the other was soaked in a 60°C water bath for three hours. After soaking, the pills were then removed from the water and weighed to determine the weight of the water absorbed (Absorption). The pills were placed into shuttle cylinders filled with water, secured into

the Schulze-Breuer Test machine and ran for three hours (about 3,600 cycles) after which they were weighed again to determine the abrasion loss in grams (Abrasion). The pills were then placed in Ruck wire baskets and suspended in an 800 ml beaker of boiling water for 30 minutes. The remains of the pill after boiling was weighed and the Integrity calculated as a percent of the original saturated pill weight. After drying for 24 hours, the percentage of aggregate filler particles that are coated with asphalt is estimated (Adhesion). All values reported represent the average result of the four pills.

Figure 2. (A) The Schulze-Breuer and Ruck Pill Press and Mold, (B) Shuttle Cylinders and Abrasion Machine, (C) Freshly Molded Pill, and (D) Abraded and Boiled Pill

3.0 RESULTS AND DISCUSSION

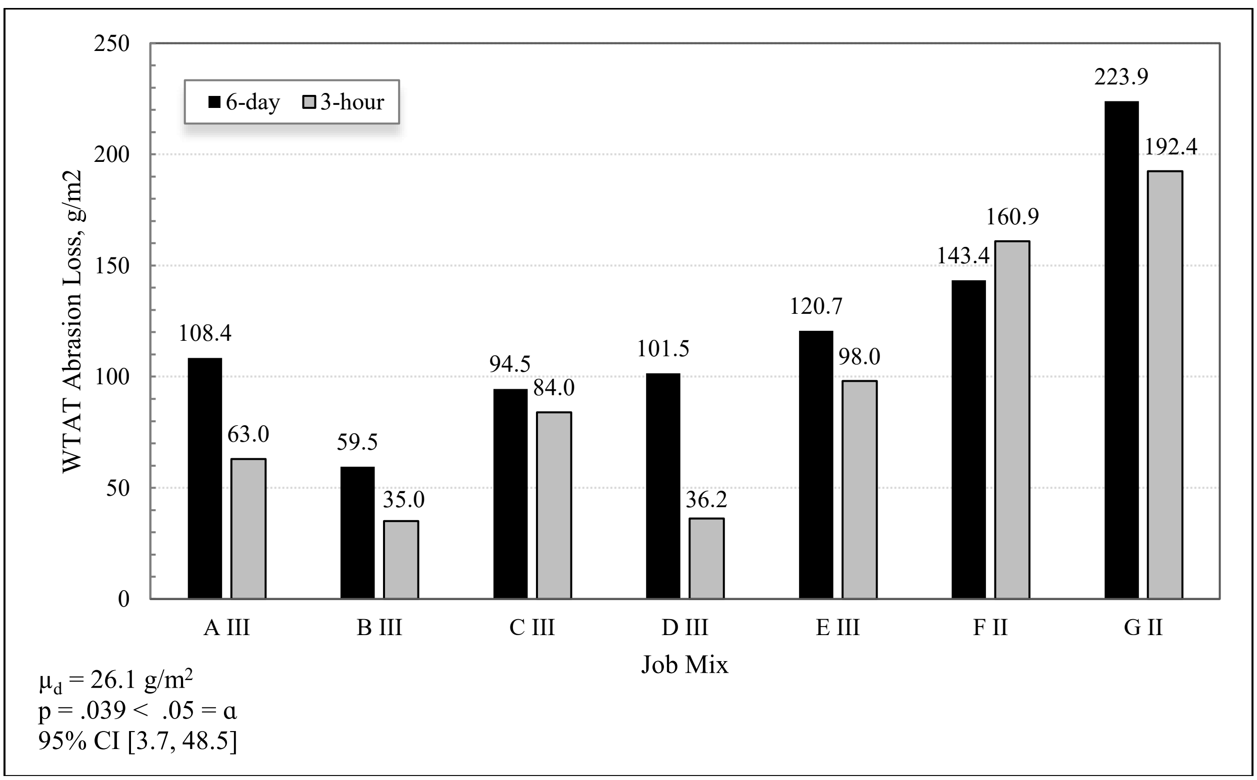
3.1 Wet Track Abrasion

Comparison of accelerated and conventional method wear values for the WTAT are depicted in Figure 3. Contrary to the findings of the original study, abrasion loss was greater for the 6-day method in all but one sample. Applying a paired t-test to the data indicates that the differences are significant at the 95 percent confidence level ($p = 0.039 < .05 = \alpha$). However, it should be noted that in previous works the repeatability and reproducibility of the ISSA mix design test methods was found to be relatively poor [2, 13].

The repeatability is such that all results for the accelerated method are within the 95 percent confidence limits of the conventional method results, suggesting that if the test was repeated by the conventional method it is conceivable results similar to the accelerated method could be obtained due to inherent variability in the test.

Overall the results for these job mixes are relatively low considering the threshold value for a 6-day WTAT is 807 g/m^2. Zhai and Rosales observed that when the abrasion loss was around 323 g/m^2 and greater, the wear values obtained by the accelerated method were consistently higher than the conventional method, however we did not approach these higher losses in the samples tested.

The WTAT soak period and the effect on results may be more complex than is assumed. For example, it is not always the case that the 6-day soak wet tracks yield a higher abrasion loss than the 1-hour conditioned samples. Yang and Liu noted this as well, which influenced them to study abrasion loss at various conditioning times. During their study, the abrasion loss reached the maximum after 48 hours conditioning and then decreased with soak time [14]. They concluded that two competing mechanisms are at work; i) moisture damage resulting in decreased adhesion, and ii) curing of the mix strengthening the aggregate asphalt bond. After 48-hours the bond strength developed by curing surpassed the moisture damage mechanism and the abrasion loss decreased with time. The effect of conditioning time on samples is no doubt system specific.

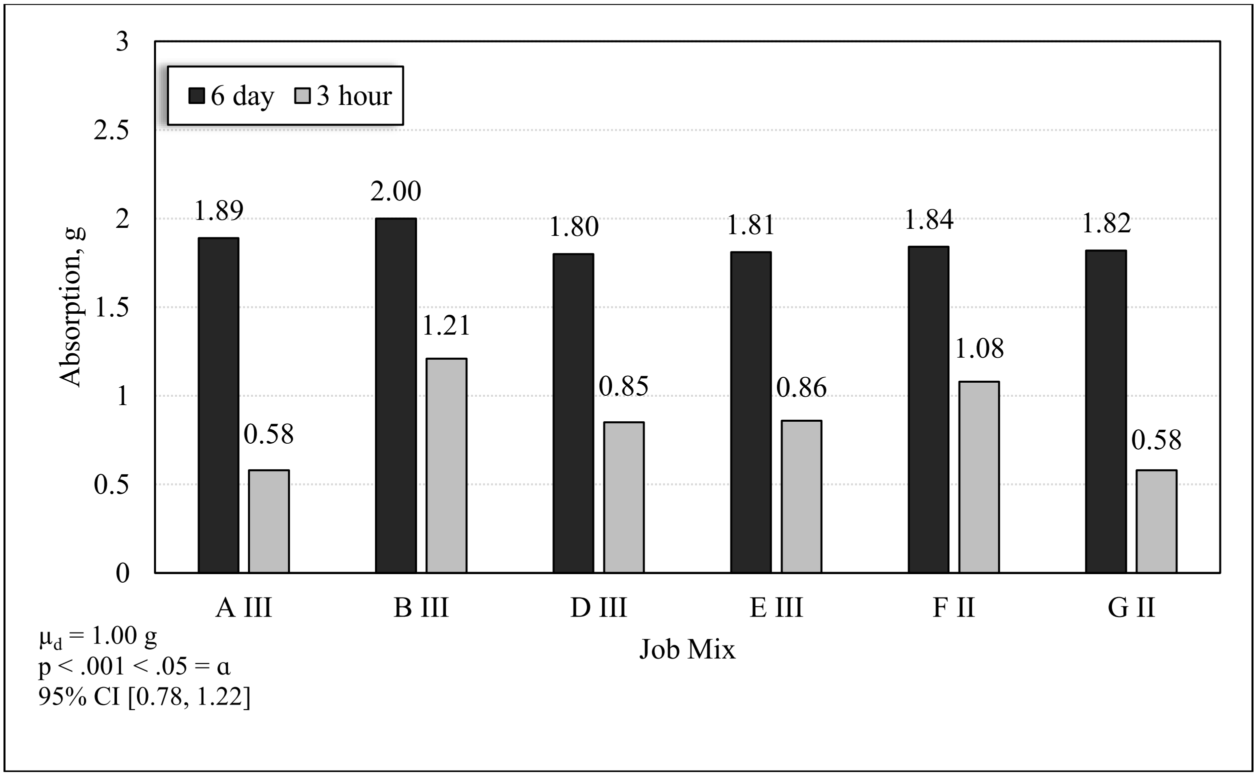


Note: WTAT is Wet Track Abrasion Test. μ_d is paired t-test mean difference and CI is 95% confidence interval for mean difference.

Figure 3. Wet Track Abrasion Wear Value (g/m^2 Loss) Comparison for 6-day Conventional Method and 3-hour Accelerated Method

3.2 Schulze-Breuer and Ruck Test

Although Absorption is not factored into the grading of the SB & R classification as it has no known correlation with abrasion loss, it is of note that the amount of absorption in the accelerated samples is significantly lower than in the conventional samples, as shown in Figure 4 [15]. Nonetheless, this study confirms that the amount of absorption does not correlate with SB & R test abrasion loss.

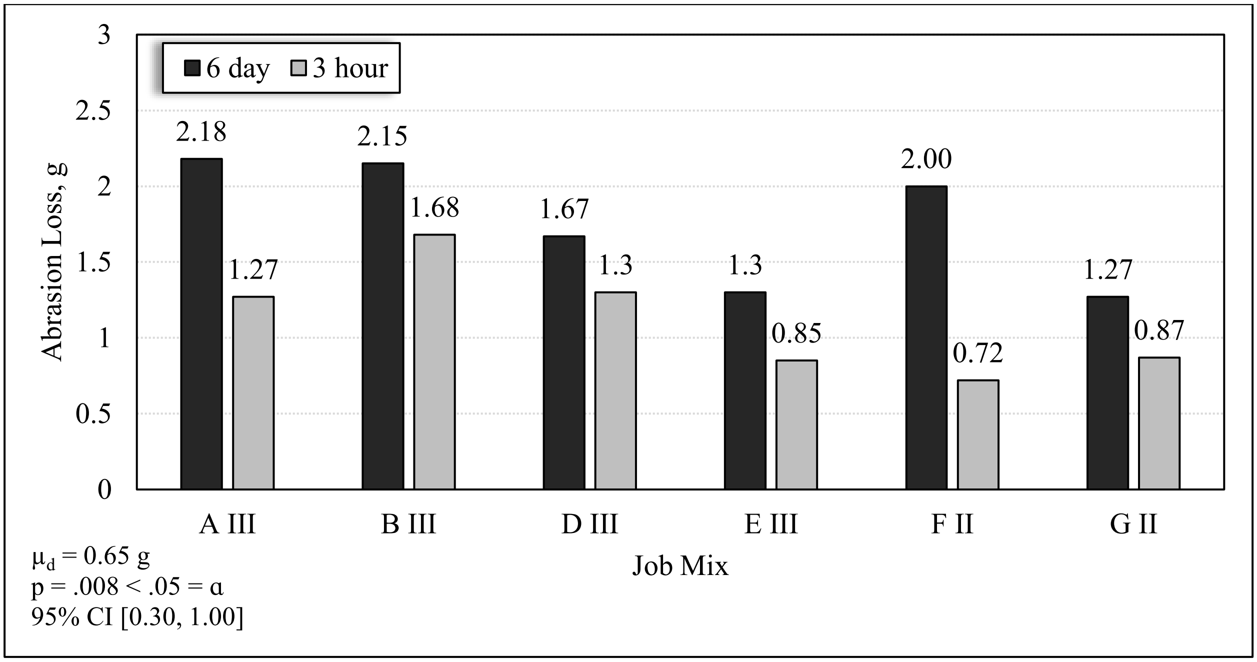


Note: μ_d is paired t-test mean difference and CI is 95% confidence interval for mean difference.

Figure 4. Schulze-Breuer and Ruck (SB & R) Absorption Comparison for Accelerated (3-hour) and Conventional (6-day) Methods

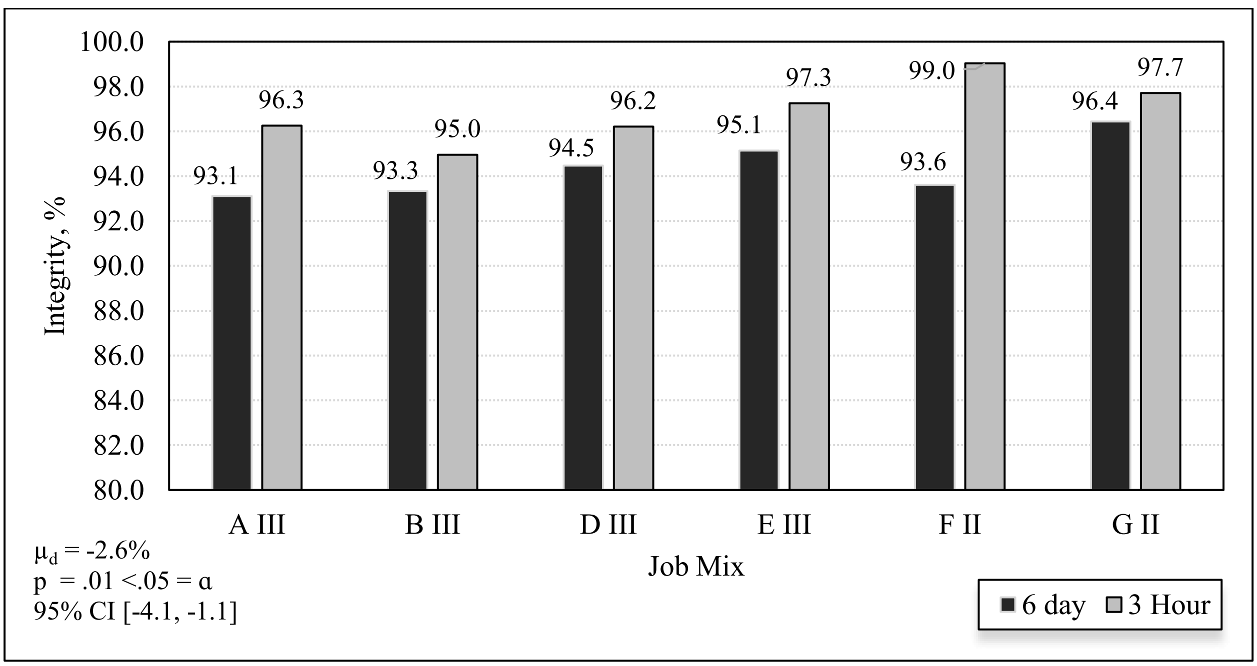
In all samples, Abrasion Loss was lower using the accelerated method (Figure 5). The difference between results obtained by the accelerated method versus the conventional method are significant ($p = .008 < .05 = \alpha$). Adhesion showed little difference with the percent estimated coating between 90 and 95 percent for all samples. The Wet Stripping Test for Cured Slurry Seal Mix (ISSA Technical Bulletin #114), perhaps a more accurate test as it is done on the complete mix, was also completed on these mixes and showed no sign of adhesion problems [16].

Results for Integrity were greater for all samples completed by the accelerated method (Figure 6). This is consistent with the fact that the Integrity calculation is based on the difference between the original pill weight and the weight after boiling, with the accelerated method pills experiencing less abrasion loss. None of the pills degraded excessively after boiling therefore achieving greater than 90 percent Integrity. As show in Table 6 it was found that the classification compatibility improved using the accelerated method for all mixes.



Note: μ_d is paired t-test mean difference and CI is 95% confidence interval for mean difference.

Figure 5. Schulze-Breuer and Ruck (SB & R) Abrasion Loss Comparison for Accelerated (3-hour) and Conventional (6-day) Methods



Note: μ_d is paired t-test mean difference and CI is 95% confidence interval for mean difference.

Figure 6. Schulze-Breuer and Ruck (SB & R) Integrity Comparison for Accelerated (3-hour) and Conventional (6-day) Methods

Table 6. Classification Compatibility for Accelerated (3-hour) and Conventional (6-day) Methods

Aggregate	Classification Compatibility	
	6-day	3-hour
A III	0AA-8	CAA-10
B III	0AA-8	DAA-9
D III	DAA-9	CAA-10
E III	CAA-10	BAA-11
F II	DAA-9	BAA-11
G II	CAA-10	BAA-11

The results of this study highlight the fact that while both the WTAT and the SB & R test are a measure of compatibility of mix materials under wet conditions, a passing WTAT does not always equate to a passing SB & R result. There is no correlation noted in this work between WTAT and SB & R abrasion loss. If the SB & R test is a measure of asphalt-filler compatibility, the mix should demonstrate poor moisture susceptibility and therefore, a high wet track abrasion loss if SB & R results are weak. However, this is not always the case likely due to the fixed grading required by the SB & R test and the resulting decreased asphalt to filler ratio. The asphalt film thickness, a factor known to have significant impact on abrasion results, is approximately 20-30 percent lower in the SB & R mix than in the WTAT or field mix. It has been suggested that completing the SB & R test with mixes that provide asphalt-filler ratios similar to those in the WTAT or field mix may reconcile the differences noted between WTAT and SB & R abrasion results, as well as provide more accurate prediction of field performance [17].

4.0 FIELD PERFORMANCE

4.1 Correlation of Mix Performance Tests to Field Performance

While ISSA A143 is the most widely used micro-surfacing specification in North America, it has been recognized that the testing and design methods are mostly empirical and results may not be related to field performance. The lack of repeatability of the ISSA tests has been questioned by several researchers as well as concluded by the California Department of Transportation (Caltrans) pooled funded study. The identified need to improve mix design procedure and specifications lead to agencies such as the Texas Transportation Institute (TTI) to develop their own micro-surfacing mix design guideline while other states have only partially adopted ISSA A143 or have fully adopted it but changed the specifications on some tests.

Guidelines are much of the time based upon anecdotal evidence and experience. ISSA A143 suggests flexibility in that not all tests need to be specified. Failure to meet a requirement for an individual test does not suggest a system should be disqualified. The results of tests performed need to be examined as a whole by an experienced designer before an optimum field mix can be selected.

The WTAT is specified in many guidelines worldwide including Austroads, Indian Road Congress (IRC), TTI, and European Standards. An extensive field study by Kori and Coyne looked at over a hundred pavements and correlated the wet track abrasion to field performance [18]. Their findings indicated that satisfactory performance was related to maximum abrasion loss of 807 g/m2, however, there are questions whether the test can properly simulate field conditions for stripping and ravelling. Some agencies such as the Ohio DOT have lowered the maximum abrasion loss for the 6-day WTAT from 807 to 650 g/m^2 [19]. It has also been suggested that the rubber hose fitted abrasion head of the Hobart mixer may not simulate the in-service abrasion loss with accuracy. Caltrans developed the Cohesion Abrasion Test (CAT), based on a French design that uses wheels on the abrasion head rather than a rubber hose.

It is generally accepted that the 6-day WTAT test has better correlation and reproducibility than the 1-hour WTAT and should be used to determine the minimum emulsion content of job mix formulas. The water content is generally determined by an experienced laboratory technician at the level that provides a stable and consistent mix; however, the liquid content in the samples can greatly influence the variability of the test responses [2, 13].

In contrast to the WTAT, the SB & R test is recommended in few specifications other than ISSA. Portions of the test, specifically the Integrity are known to fail despite good performance in the field [2]. The test overall may be sensitive to the type of asphalt used as well as the type of polymer modification [2, 20]. It has been suggested that the SB & R test may be able to better assess the performance of polymer modified emulsion, however, in testing there was no distinction between unmodified and modified mixes with respect to the adhesion and absorption parameters [20]. As previously noted, the SB & R mix does have a higher ratio of mineral filler to active filler and a significantly lower asphalt film thickness than the actual field mix, and therefore may not provide a useful measure of field performance.

4.2 Field Observations

Field observations of selected pavement sections in western Canada and northern United States were completed to determine if results of mix performance tests correlated with field performance. All the sections were completed in 2017 so comparisons can be drawn on how they are currently performing after one year in service.

4.2.1 Job Mix D III

The mix design data for Job Mix D III is presented in Table 7. The aggregate for this work has been used in several micro-surfacing designs across the Western provinces for many years. The work occurred on a 14-kilometre section in eastern Manitoba on a high-volume roadway. The underlying pavement exhibited transverse and longitudinal cracks with rut depths ranging from 8 to 14 mm deep. Prior to micro-surfacing the road was swept with a power broom. The job consisted of both rutfill and surface overlay and was completed in fair weather (18 to 25°C) from mid to the end of June. The designed micro-surfacing system worked well with a return to traffic time of about 45 minutes, however if the emulsion received was too hot or the ambient temperature rose above 25°C, clumping would occur and result in drag marks.

After one season the pavement is in good shape (Figure 7); this is a good example of choosing the right candidate for this type of pavement preservation technique. Existing transverse cracks have reflected through the surface within the year, however, they are minimal. Some minor non-uniformity is observed, which may be related to the underlying pavement and slight mix segregation due to balling formed by the emulsion breaking too quickly. There is very slight wear noted in the wheelpaths and no significant snowplowing damage.

Table 7. Job Mix Testing Results for Mix D III

Test	Results	Specification
Mix Time at 25°C	280	Controllable to ≥ 120 seconds
Wet Cohesion		
30 minutes (set)	14	≥ 12 kg-cm
60 minutes (traffic)	21	≥ 20 kg-cm
Wet Stripping	100	≥ 90%
Wet Track Abrasion Loss		
1-hour soak at 25°C	52.6	≤ 538 g/m^2
6-day soak at 25°C	101.5	≤ 807 g/m^2
3-hour soak at 60°C	36.2	
Lateral Displacement	1.6	≤ 5%
Specific Gravity	2.07	≤ 2.10
Excess Asphalt by LWT	365.4	≤ 538 g/m^2
Classification Compatibility		≥ 11 points (AAA, BAA)
6-day soak at 25°C	DAA-9	
3-hour soak at 60°C	CAA-10	
Job Mix Formula (cement/water/emulsion)	1/8/12	As Required
Residual Asphalt	7.8	5.5 - 10.5%

Figure 7. Highway Section Completed Using Job Mix D III in Eastern Manitoba

4.2.2 Job Mix E III

Job Mix E III was used on a 12-kilometre section in southwestern Manitoba. The mix design details and performance testing are shown in Table 8. The goal of the micro-surfacing was for rutfill and reprofiling to restore good drainage. The underlying highway was in reasonable shape so just the shoulders were swept prior to application. The work took place under good conditions and favourable weather (26 to 29°C). Rutfill was completed and then a single overlay of micro-surfacing. The project experienced a delay due to insufficient aggregate supply; the contractor left the project for one month before returning to complete it. Initially the mix experienced some setting problems but, after adjustment, it laid down well and the return to traffic was about an hour.

Table 8. Job Mix Testing Results for Mix E III

Test	Results	Specification
Mix Time at 25°C	270	Controllable to ≥ 120 seconds
Wet Cohesion 30 minutes (set) 60 minutes (traffic)	 18 22	 ≥ 12 kg-cm ≥ 20 kg-cm
Wet Stripping	100	≥ 90%
Wet Track Abrasion Loss 1-hour soak at 25°C 6-day soak at 25°C 3-hour soak at 60°C	 85.7 120.7 98.0	 ≤ 538 g/m^2 ≤ 807 g/m^2
Lateral Displacement Specific Gravity	1.1 2.03	≤ 5% ≤ 2.10
Excess Asphalt by Loaded Wheel Tester (LWT)	255.8	≤ 538 g/m^2
Classification Compatibility 6-day soak at 25°C 3-hour soak at 60°C	 CAA-10 BAA-11	≥ 11 points (AAA, BAA)
Job Mix Formula (cement/water/emulsion)	1/8/11	As Required
Residual Asphalt	7.15	5.5 - 10.5%

Overall this section appears to be well-constructed and performing well after one season. Photos of this section can be seen in Figure 8.

There is segregation visible in some areas that might be related to problems with oversized material and balling of emulsion due to dusty aggregate. There is moderate reflective and longitudinal cracking in some areas and in rare instances the cracking is severe and has resulted in loss of the micro-surfacing in the immediate area. Some minor wear is noted in the wheelpaths, perhaps a bit more than should be expected after one season, but not entirely outside the norm for micro-surfacing jobs in this area and with the available aggregates. Intermittent slight damage along the centerline is evident likely related to snow plowing.

Figure 8. Highway Section Completed Using Job Mix E III in South Western Manitoba

4.2.3 Job Mix G II

Details for Job Mix G II are shown in Table 9. This mix was used on a 48-kilometre section of highway in southern North Dakota that exhibited severe rutting. This was a test section that applied three different procedures including: 1) a single micro-surfacing overlay, 2) a double micro-surfacing overlay on a milled surface and, 3) a micro-milled surface with a micro-surfacing overlay. The work was completed in July of 2017 under good weather, which was general between 23 and 26°C. The micro-surfacing system worked well with traffic being turned back onto the roadway in about 20 minutes.

Table 9. Job Mix Testing Results for Mix G II

Test	Results	Specification
Mix Time at 25°C	280	Controllable to ≥ 120 seconds
Wet Cohesion 30 minutes (set) 60 minutes (traffic)	15 20	≥ 12 kg-cm ≥ 20 kg-cm
Wet Stripping	100	≥ 90%
Wet Track Abrasion Loss 1-hour soak at 25°C 6-day soak at 25°C 3-hour soak at 60°C	166.2 223.9 192.4	≤ 538 g/m^2 ≤ 807 g/m^2
Lateral Displacement Specific Gravity	4.1 2.04	≤ 5% ≤ 2.10
Excess Asphalt by Loaded Wheel Tester (LWT)	222.2	≤ 538 g/m^2
Classification Compatibility 6-day soak at 25°C 3-hour soak at 60°C	CAA-10 BAA-11	≥ 11 points (AAA, BAA)
Job Mix Formula (cement/water/emulsion)	1/8/11	As Required
Residual Asphalt	7.15	5.5 - 10.5%

After one season the roadway has experienced significant cracking (Figure 9).

Figure 9. Highway Section Completed Using Job Mix G II in Southern North Dakota

The cracking consists of regular transverse cracking as well as severe centerline and random cracking. Subsequently, the entire section has been repaired with hot pour crack filler. Cracking may be less severe in the section that was milled and then a double layer of micro-surfacing applied. The excessive cracking throughout the project regardless of rehabilitation method used is likely indicative of a structurally inadequate pavement and therefore, an unsuitable candidate road. The pavement texture is uniform aside from some small areas of flushing noted near the centerline rumble strips. The workmanship on this section is very good and aside from the cracking, there are no other defects visible. Additionally, the sections completed by different methods are nearly indistinguishable from each other.

4.2.4 Summary of Field Observations

As mentioned, the results for the WTAT for all of the job mix designs were relatively low with respect to the ISSA suggested threshold values for 1-hour and 6-day abrasion losses of 538 and 807 g/m^2, respectively. While there is no ravelling observed, the two Type III mixes in particular, are starting to show a slight bit of wear in the wheelpaths after one year. It is difficult to determine whether the wear is related to the mix, construction or environmental causes, or a combination thereof. It has been noted that this type of minor wear is not considered uncommon for micro-surfacing projects in this area possibly due to lack of availability of ideal aggregates and the harsh winters. This observation suggests perhaps mix design specifications, specifically the WTAT, should be calibrated to harsher freeze-thaw climates. A lower acceptable threshold for abrasion loss, such as that adopted by the Ohio DOT may be able to more accurately indicate those designs that could be at risk for significant wear.

Additionally, changes in mix design methodology and control of the mix in the field may reduce susceptibility to wear and reconcile discrepancies that may exist between results observed in laboratory mix tests and performance in the field. As previously stated, WTAT results are highly sensitive to both water and asphalt binder content. Subscribing to an exact procedure for ideal water content determination rather than relying on the subjective opinion of the laboratory technician may reduce the variability in the test response and aid in more accurate selection of minimum asphalt binder content for optimum field performance.

In many cases mix designs will specify acceptable ranges for all components but suggest water be added as contractors deem necessary to control the mix. The designs included in this work had a suggested range for water content of ±3 percent allowable deviation from the job mix formula. Controlling water content in the field is imperative to performance as inappropriate water content can result in mix segregation. Insufficient water can result in settlement of the binder and fines to the lower portion with larger aggregate particles at the surface where they are more rapidly abraded. Alternatively, excess water can lead to a portion of the binder and fines migrating to the surface leaving coarse aggregate particles in the lower fraction lacking sufficient binder.

All SB & R results for the examined pavements failed or were considered marginal according the ISSA suggested classification guideline. Excessive wear can be a sign of aggregate-binder incompatibility; however, other compatibility tests, specifically the WTAT and Wet Stripping Test indicated that the job mix components were sound. Field observations do indicate some very slight wear but it seems more suggestive of mix segregation issues than compatibility problems with the mix.

Perhaps as previously suggested, for this test to be a useful measure, asphalt film thicknesses should duplicate that of the field mix. Alternatively, the specification threshold could be adjusted to accommodate this shortfall. For example, the Departments of Transportation in some American states refer to ISSA TB 144 as Saturated Abrasion Compatibility with a 3 g maximum abrasion loss specified [19, 21]. While the

Schulze-Breuer portion of the SB & R test, more specifically the abrasion, is known to be a reasonably precise test response, the Ruck procedures are suspect and therefore, are eliminated in some micro-surfacing design specifications that do recommend this test.

The fact that cracks have reflected through after less than one-year attests to the fact that micro-surfacing provides no structural support and does very little to slow the progression of these cracks. Perhaps performance with respect to retarding of cracks could have been improved if the cracks were treated prior to micro-surfacing.

Although slight snow plow damage is visible on these sections it is not unexpected in our northern climates; however, if the underlying pavements are structurally sound it should not adversely impact the benefits of micro-surfacing as rutfill, reprofiling, or ride quality improvement.

5.0 CONCLUSION

This study was conducted to determine whether an accelerated method could replace the required 6-day soak for the micro-surfacing WTAT and SB & R tests. Based on our findings, a shorter soak time at elevated temperature is not a severe enough condition to replicate results gained by the full 6-day soak. In all but one job mix, the WTAT results were lower utilizing the accelerated conditioning method. Similarly, abrasion loss on SB & R pills was also lower for all mixes resulting in an increase of at least one compatibility class.

It is difficult to conclude why the results of this study were different than those of the original research by Zhai and Rosales [3]. Emulsion binder residue interaction with aggregate is complex and it can be expected that binder has a significant effect on micro-surfacing design test results. Any change in the asphalt properties will change the performance of the mix. Although the aggregates varied, both this research and the original study utilized one asphalt emulsion manufactured with the same asphalt binder and emulsifier. Perhaps the micro-surfacing system itself contributes more variability in test responses and should be further studied. Additionally, conditioning time effect on samples may be more complex than is assumed with potential moisture damage being mitigated by strengthening of the asphalt aggregate bond through extended curing time.

Observations of field performance of selected job mixes indicates that there is some slight wear observed in the wheelpaths on two of the sections, however, it is more likely a result of mix segregation where coarse aggregate is concentrated at the surface and easily abraded. The pavements are generally free of defects that would indicate poor compatibility suggesting the SB & R test as currently described by the ISSA can be used to gather information about mix characteristics, but not necessarily to eliminate or select micro-surfacing systems. The WTAT can accurately predict the wearing qualities of a mix in the field, however, it must be noted that the test is sensitive to water content used in the preparation of samples to ensure accurate and repeatable results from which to select the optimum binder content for the system.

While the accelerated method studied did not supply results statistically similar to those obtained by the conventional soak method, the concept is valuable enough to warrant further study. The McAsphalt Western Research Centre will continue to do further testing to determine if minor extensions in soak time at elevated temperature can reconcile the differences in results obtained to those obtained by the conventional conditioning.

REFERENCES

[1] International Slurry Surfacing Association (ISSA) A143. “Recommended Performance Guideline for Micro Surfacing”, Annapolis, Maryland (revised 2010).

[2] Andrews EM, Smith RE, Beatty CK, Button JW. “Evaluation of Micro-Surfacing Mixture Design Procedures and Effects of the Material Variation on the Test Responses”, Report No. FHWA/TX-95/1289-1, Federal Highway Administration, Washington, D.C. (revised April 1995).

[3] Zhai H, Rosales A. “Accelerating Micro Surfacing Mix Design Process” Pavement Preservation and Recycling Alliance (PPRA). http://ppralliance.org/dave-zhai-accelerating-micro-surfacing-mix-design-process-7-25-17 (July 27, 2017).

[4] International Slurry Surfacing Association (ISSA) Technical Bulletin No. 144. “Test Method for Classification of Slurry Surfacing Materials Compatibility by Schulze-Breuer and Ruck Procedures”, Glen Ellyn, Illinois (revised 2013).

[5] ASTM International (ASTM) Standard C136/C136M-14. “Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates”, Annual Book of ASTM Standards, Concrete and Aggregates, 04-02, West Conshohocken, Pennsylvania (2017).

[6] ASTM International (ASTM) Standard C117-17. “Standard Test Method for Materials Finer than 75-µm (No.200) Sieve in Mineral Aggregates by Washing”, Annual Book of ASTM Standards, Concrete and Aggregates, 04-02, West Conshohocken, Pennsylvania (2017).

[7] American Association of State Highway and Transportation Officials (AASHTO) T 176-17. “Standard Method of Test for Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test”, Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part 2B, 2018 Edition, Washington, D.C. (2018).

[8] International Slurry Surfacing Association (ISSA) Technical Bulletin No. 145. “Test Method for Determination of Methylene Blue Adsorption Value (MBV) of Mineral Aggregate and Fillers and Fines”, Annapolis, Maryland (revised 2013).

[9] International Slurry Surfacing Association (ISSA) Technical Bulletin No. 113. “Test Method for Determining Mix Time for Slurry Surfacing Systems”, Glen Ellyn, Illinois (revised 2017).

[10] International Slurry Surfacing Association (ISSA) Technical Bulletin No. 139. “Test Method to Determine Set and Cure Development of Slurry Surfacing Systems by Cohesion Tester”, Glen Ellyn, Illinois (revised 2017).

[11] International Slurry Surfacing Association (ISSA) Technical Bulletin No. 100. “Test Method for Wet Track Abrasion of Slurry Surfaces”, Glen Ellyn, Illinois (revised 2018).

[12] International Slurry Surfacing Association (ISSA) Technical Bulletin No. 144. “Test Method for Classification of Slurry Surfacing Materials Compatibility by Schulze-Breuer and Ruck Procedures”, Glen Ellyn, Illinois (revised 2013).

[13] Robati M, Carter A, Perraton D. "Evaluation of Repeatability and Reproducibility of Micro-Surfacing Mixture Design Tests and the Effect of Total Aggregate Surface Areas on the Test Responses" Australian Journal of Civil Engineering, 11 (1), 41-55 (2013).

[14] Yang S, Liu G. "Using Packing Theory to Improve Micro-Surfacing Mix Design Procedure and Evaluating It's Long Term Performance" Presented at the 96th Annual Meeting of the Transportation Research Board, National Research Council, National Academies, Washington, D.C. (2017).

[15] Guiles N. "Affects of Variables on the Schulze-Breuer-Ruck Classification Procedure", 31st Annual International Slurry Surfacing Association (ISSA) Conference, Palm Springs, California (1993).

[16] International Slurry Surfacing Association (ISSA) Technical Bulletin No. 114. "Test Method for West Stripping of Cured Slurry Surfacing Mixtures", Glen Ellyn, Illinois (revised 2017).

[17] Ng T, James A. "Comparisons Between Schulze-Breuer & Ruck and Wet Track Abrasion Test Results", 39th Annual International Slurry Surfacing Association (ISSA) Conference, Maui, Hawaii (2001).

[18] Skog D. "Wet Track Abrasion Testing", Technical Report 70-19, California Department of Transportation (1970).

[19] "Construction and Materials Specification", Item 421, State of Ohio Department of Transportation, Columbus, Ohio (2013).

[20] Johnston J, King G. "Using Polymer Modified Asphalt Emulsions in Surface Treatments", Federal Lands Highway Interim Report, Federal Highways Administration (FHWA), Washington, D.C. (2008).

[21] "Standard Specifications for Construction", Section 504, Michigan Department of Transportation, Lansing, Michigan (2012).