

Evaluation of the Suitability of the Automated Mixing Test in Determining the Workability of Slurry Surfacing Mixes

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Synopsis— Slurry seals and micro-surfacing systems are widely used as primary surface treatments for extending pavement life and restoring the serviceability function of structurally adequate pavements. Beside their prevalent use, current test methods and procedures for evaluating the workability properties of slurry surfacing mixtures remain empirical, with no apparent agreement among practitioners. The performance of slurry surfacing seals is dependent the quality of the construction process, which is in turn dependent on the workability of the mixtures during construction. This study evaluated the suitability of using the Automated Mixing Test (AMT) in determining the workability parameters of slurry surfacing systems. The results of this study showed that workability is highly affected by emulsion type (cationic vs anionic, modified vs unmodified), gradation and aggregate gradation.

Keywords—*slurry seals, workability, automated mixing test*

I. INTRODUCTION

Slurry and micro-surfacing seals are some of the most important tools used for the maintenance and preservation of pavements world over. A slurry seal is a mixture of a slow setting bitumen emulsion, well-graded fine aggregate, mineral filler, and water [1]. It is used for various purposes such as to fill cracks, protect aged pavements, address ravelling, or to make cape seals. A micro-surfacing on the other hand can be described as a “high-performance slurry seal”. It is usually made

with higher quality materials than those used for slurry seals, such as strictly 100% crushed aggregate and polymer modified cationic emulsion [2]. A micro-surfacing can be used to fill ruts in addition to the functions of a slurry seal. The two surfacing are similar in terms of the ingredients used, appearance, functions, and exhibit similar failures in the field. It for these reasons that the two seals are referred to as *slurry surfacing systems/seals* (SSS) in this paper henceforth.

Slurry surfacing systems are cost-effective, energy efficient and environmentally friendly compared to the traditional hot mix asphalt (HMA) overlays. They are applied in smaller thicknesses that allow road agencies to resurface three to 5 times more kilometres of the road surface with the same budget used for HMA overlays [3]. Unlike HMA mixes, mixing and construction is carried out at room temperature, resulting in savings on heating and reduced greenhouse gas emission. Construction is carried out with relatively basic construction equipment, making them attractive alternatives for rural areas and developing countries.

Slurry surfacing systems do not have any structural capacity; they are strictly applied to address the functional failures of pavements. When placed on the "right pavement at the right time" slurry surfacing seals can extend the life of the pavement for up to 5 years, depending on the road category, quality of the materials used and the quality of the construction process [3].

One of the key challenges faced by road contractors during the construction of slurry surfacing systems is poor workability. Current International Slurry Surfacing Association (ISSA) and ASTM laboratory test procedures for determining the workability parameters of slurry surfacing mixes are empirical and operator dependent. Secondly, although slurry seals and micro-surfacing systems are basically made-up with the same ingredients, the criteria for determining workability for each surfacing varies among practitioners and in current specifications and guidelines. Various equipment for evaluating the workability of slurry surfacing mixes, such as the Automated Mixing Test (AMT), have been reported to be promising in evaluating the workability of slurry surfacing seals in an objective manner [4]. However, the suitability of the AMT in determining the workability of slurry surfacing mixes has not been thoroughly evaluated, and there is not much information on the use of the AMT in determining the workability of slurry surfacing systems.

The main objective of this study is to evaluate the suitability of the AMT in determining the workability parameters (mixing time, water content, mixture consistency) of slurry surfacing mixes in an objective manner.

II. BACKGROUND

A. *Workability of Slurry Surfacing Systems*

Workability can be defined as the ease with which a mixture of the slurry surfacing system can be mixed, placed and finished without experiencing problems [5]. The mixture should remain workable during mixing (i.e. should not experience premature breaking) to allow for all ingredients to be mixed into a creamy-smooth homogenous mixture. The fresh mixture should also remain workable enough to allow for ease of placement and finishing. The mixture should remain soft, creamy and homogenous to be able to flow from the mixing truck (in the case of mechanically placed slurry

surfacing systems) or to enable spreading around with squeezes in the case of hand placed slurry-surfacing systems [5]. The slurry surfacing systems must also be of a low enough consistency to be able to flow into surface cracks, but should have sufficient viscosity not to drain off the road surface on steep gradients and to prevent segregation.

B. Factors Affecting the Workability of Slurry Surfacing Systems

Factors affecting the workability of slurry surfacing mixtures include: the amount of mixing water, emulsion content, amount of filler, amount and type of additive, the chemical compatibility of the aggregate and bitumen emulsion used, mixing temperature, the chemistry of the emulsion and aggregate used [5-6]. Workability generally increases with increase in mixing water or emulsion content for a chemically compatible system, however, excess water can lead to segregation. The workability window may decrease with increase in temperature due the chemical nature of the slurry surfacing systems. Workability may also decrease if high filler (cement) content is used, but the filler generally helps in preventing segregation. While slurry surfacing mixtures made with aggregate-emulsion combinations that are incompatible, will not give good workability no matter the amount of mixing water or temperature [6]. The amount of optimum mixing water and compatibility of the aggregate-emulsion combination (to be used) is determined during the mixture design process.

C. Common In-service Failures Related to Workability

Poor mixture workability can result in catastrophic failures of slurry surface systems in the field. One of the main workability related failures is insufficient mixing time. This occurs when the emulsion breaks during mixing of the components, such that satisfactory aggregate coating and proper mix consistency for placement cannot be achieved [7]. Mixes experiencing this problem are generally stiff in nature and tend to form “balls” and “lumps”, and as such cannot be placed and finished to a desired thickness. The mechanisms causing premature breaking are still not well understood. Factors contributing to insufficient mixing time include emulsion properties, aggregate properties, amount of premixing water added, amount of filler added, and temperature of the mixture at the time of mixing [6-8].

The main factor reported to affect mixing time is the amount of premixing water used [7-8]. Water is generally added to slurry surfacing mixes in order to achieve a desired level of mixture consistency and workability window. If the amount of water added is not enough, premature breaking may occur. However, excess amount of premix water may result in segregation, which in turn leads to premature failure of surface treatment in service. Aggregate with high absorption or high zeta potential values, and/or high fine/filler or clay contents, have also been reported to cause problems with premature breaking [9-10]. High temperatures have also been report to contribute to premature breaking, as it tends to increase the breaking rate of emulsions which may result in an insufficient workability window [8].

Another common mixture failure is related to workability is segregation. Segregation occurs when there is physical phase separation between different components of the mixture due to differences in their density [11]. In the case of slurry surfacing mixes the emulsion and fine particles floats to the surface of the seals, while the coarser aggregate particles settle out to the bottom. The emulsion that

rises to the top of the surface usually wears off due to traffic abrasion, leaving a harsh mixture behind with insufficient binder to bind the aggregate on the road under traffic [12-13]. As a result, the surface disintegrates quickly afterward in a form of aggregate loss, and may also de-bond from the existing substrate [13]. The main factor contributing to segregation is excessive premixing water content, although excessive use of additives has also been reported to result in mixture segregation [13].

D. Test Method for Workability of Slurry Surfacing Systems

Test methods for evaluating the workability of slurry surfacing systems found in literature are given in Table I, including the advantages and disadvantages of each test method. This study focused mainly on evaluating the AMT because of its advantages of being automated and non-operator dependent, while current test methods in ISSA TB A143 [2] and ISSA TB A105 [14] specification were used to validate the results of the AMT.

TABLE I. TEST METHODS FOR EVALUATING THE WORKABILITY OF SLURRY SURFACING SEALS

Test Method	Description	Source	Advantages	Disadvantages
Mix Time Test	A sample of a mixture is mixed continuously in a paper cup by hand at 25 °C. Mixture should remain workable for at least 120 seconds.	ISSA TB 113	Simple and requires no sophisticated equipment or highly educated operator. Widely used.	Subjective and operator dependent
Automatic Mixing Test	Measure time required for the mixture to reach a specified torque, when a sample of a mixture is continuously mixed by a shear mixer.	Fugro [4]	Automated test, measures engineering parameters that affects workability in the field.	Lack of results, and not used by many people. Equipment specifications and testing parameters not yet well defined.
Consistency	Measure the flow of a mixture sample from a standard cone, similar to the slump test used for determining the workability of concrete. The mixture must flow at least 2 to 3 cm to qualify as workable.	ISSA TB 106	Very simple, easy and straight forward. Commonly used and very repeatable.	Test is empirical and could be operator dependent. Not applicable to some polymer modified and quickset emulsion types.

III. METHODOLOGY

A. *Materials Used*

- Bitumen Emulsions:

Four emulsions with varying chemistry commonly used in the United States were obtained from various suppliers in Wisconsin. Table II presents the type and properties of the emulsions used. The emulsions were selected such that the effects of chemistry (cationic vs. anionic), and polymer modification on the mixture performance could be evaluated. All emulsions used met the ISSA A143/A105 [2] [14] guidelines for emulsions used for slurry seals and micro-surfacing applications.

TABLE II. PROPERTIES OF EMULSIONS USED IN THIS STUDY

Engineering Properties	ASTM Standard	Emulsion Type		
		SS-1H	CSS-1H	CSS-1HL
Saybolt Furol sec.viscosity @ 25°C	D7496	24	26	30
Residual Bitumen Content (%)	D7497	64.9	65	67.4
MSCR, Jnr@ 64°C	D7405	5.2	4.1	2.1
ER- DRS (%)	-	15	18	32

- Aggregates:

All samples were prepared with one type of aggregate, a granite commonly used in slurry surfacing systems in Wisconsin. The granite had an absorption of 0.7 %, bulk specific gravity of 2.61 and a sand equivalence of 64. The aggregates were taken from the stock piles of manufactured aggregate from suppliers, washed and dried at 120°C overnight to remove all water to allow for better control of the mixing water.

- Aggregate gradations:

Two aggregate gradations, fine and coarse, were selected. The gradations were all in the range of the two commonly used ISSA A143 gradations, Type II and Type III [3].

- Mixing water:

All samples were prepared with deionized water to eliminate problems that may arise from incompatibility between the bitumen emulsion and dissolved-ions sometimes present in tap water. No other chemical additives were used.

B. *Experimental Plan*

The Experimental Plan used is presented in Table III. Testing was carried out using a sample size of 350g of dried aggregate, batched to match each gradation. Three replicates were measured for each level of water content, allowing for the repeatability to be established. All samples were prepared at a fixed emulsion content that gave a film thickness of 8 micron calculated using the Surface Area Method described in ISSA A105. The amount of mixing water was calculated based on the saturated surface dry condition (SSD) of the aggregate. The amount of water required to reach the SSD condition of the granite aggregate used in this study was 0.7% of the dry weight of the

granite aggregate used. This approach of determining the mixing water content using the SSD of the aggregate as reference was deemed to be much more practical and accurate compared to current practice of determining the amount of mixing water as a percentage of the weight of the aggregate. The weight of the aggregate is dependent on the specific gravity of the aggregate, and thus cannot be used to compare aggregates of with different specific gravities.

TABLE III. EXPERIMENTAL PLAN

Factors	Levels	Description
Emulsion Type	2.5	CSS-1H, CSS-1HL, SS-1H
Water Content (x SSD)	3	4, 8, 16
Gradation	2	Fine and Coarse
Replicates	3	N/A
Test Methods	2	ISSA A143 & A105 and AMT
Total	90	

x SSD water amount added in relation to the amount required to reach the SSD condition of the aggregate.

c. Test Method and Test Procedures

- Hand Mixing Test (ISSA TB 113)

The minimum allowed water to prevent premature breaking or to keep the mixture workable for three minutes was determined by the Hand Mixing Test contained in ISSA TB113. This test requires a sample of a slurry surfacing mixture to be mixed continuously with a spatula in a paper cup by hand at 25 °C. Mixes that do not remain workable for less than 3 minutes (or 2 minutes for micro-surfacing) are rejected. No guideline is given regarding the number of replicates to be prepared but three replicates were performed in this study.

- Segregation Test (ISSA TB A105)

The maximum allowed water to prevent segregation were determined with the segregation test following the guidelines of ISSA TB A105. To prevent segregation, ISSA TB A105 recommends running a combination of the Consistency Test (ISSA TB 106) and a Static Segregation Test (Also known as the Split Cup Method) [15]. The horizontal slump is required to be between 2 and 3.5 cm, while results of the segregation test are all limited to a maximum of 15% difference in residual bituminous binder content of the top and bottom halves of the mixture.

- The Automated Mixing Test (AMT)

The ATM test was first evaluated and recommended by Fugro [4]. The schematic of the AMT test device and its components is shown in Fig.1. The mixing stirrer connected to the electric mixer is immersed in the sample. The electric mixer has a torque transducer which allows for the torque of a mixture to be measured during the mixing process. The electric mixer is connected to a computer, which automatically records the torque level during the testing process. At the end of the test, the torque is plotted against time, and the resulting curve analysed for workability and constructability indices to establish optimum water content for workability.

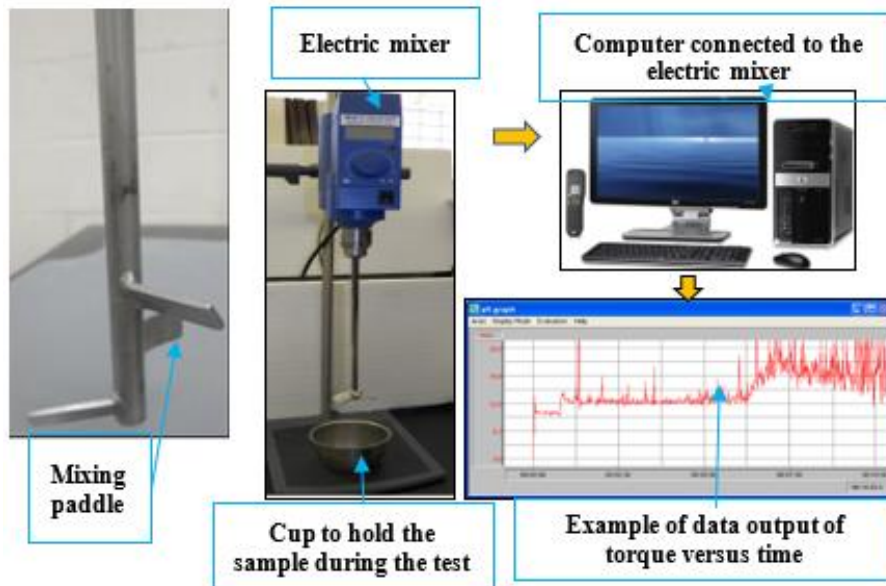


Fig. 1. Schematic of the various components required for the slurry system workability with the AMT test.

The total system assembly used in this study comprises of the following components:

- i. IKA® EUROSTAR Power Control-Visc Stirrer kit with a speed range of 50 to 2000 rpm and a stirring capacity of 40 liters.
- ii. An RS-232-C analog interface for recording speed and torque.
- iii. A Labworlsoft 4.5 software by IKA Werke that enables simple and efficient automation of experiments. It allows for the mixing torque to be automatically recorded in Microsoft Excel during the experiment.
- iv. A stainless mixing bowl with a capacity of 296 cm³, 7 cm tall, 5 cm radius with a rounded flat bottom (Vollrath #99637).
- v. A mixing stirrer with the following geometries adapted from Gudimettla et al. [15]: the bottom blade is at 45° to the direction of rotation to lift the mix from the bottom of the container. The middle blade is at 90° to the direction of rotation of the shaft, but curved slightly to prevent segregation. The top blade is at 45° to the direction of rotation of the shaft to force the mix downward. The three blades have a length of 50 mm and a thickness of 2 mm. The diameter of the shaft is 10 mm. This stirrer was found to give better results compared to the Velp scientific stirring shaft 400 mm long and shaft diameter of 7 mm, with 3 stainless steel blades, 60mm diameter recommended by Fugro [4]. The mixing stirrer recommended by Fugro [4] proved challenging as it was not able to keep the mixture homogenous for cationic emulsion, constantly resulting in a shear wall created in the mixture.

- Sample preparation and Testing Procedure for the AMT

The testing procedure used was as follows:

1. The Labworlsoft 4.5 software was programmed to run the AMT at a constant speed of 50 revolutions per minute (RPM) based on the recommendation of previous researchers [4] for a time duration of 10 minutes.
2. Prior extensive testing was done to establish the proper clear distance between the bottom of the bowl that contains the mixture sample and the mixing stirrer. The testing gap of 13 mm was used for the coarse gradation and 6.5 mm for the fine gradation.
3. The procedure for testing the samples in the AMT was established as follow:
 - i. The AMT is allowed to run for one minute with no sample in the mixing bowl to establish a zero point. Aggregate premixed with water by hand are added into the mixing bowl without stopping the test. The test is further allowed to run for two minutes until the torque level reaches a constant value.
 - ii. The emulsion is quickly added to the mixture and the equipment allowed to run for a total test time of 10 minutes. This time was deemed sufficient based on current practice that requires workability to be evaluated for a period of 2 minutes for modified emulsions and 3 minutes for unmodified emulsions.

The schematic of the testing procedure established is given in Fig.2. The result shows how the torque changes when different mixture components are added at different stages. The results also show that the equipment has a torque value of 10 N.cm when with sample in the bowl. The equipment manufacturer did not include calibration information. The values of 10 N.cm was taken as the zero point, and was subtracted from all results that were later measured to obtain the true torque value. The median filtering method (MFM) was applied to the results of the AMT to remove the scatter. The test was found to give reasonably good repeatable results as the replicates were reasonably close as show in Fig.3. The results were evaluated at different intervals: immediately before the emulsion is added to the aggregate (taken as zero mixing time or reference point), at one, two and three minutes of mixing after the addition of the emulsion.

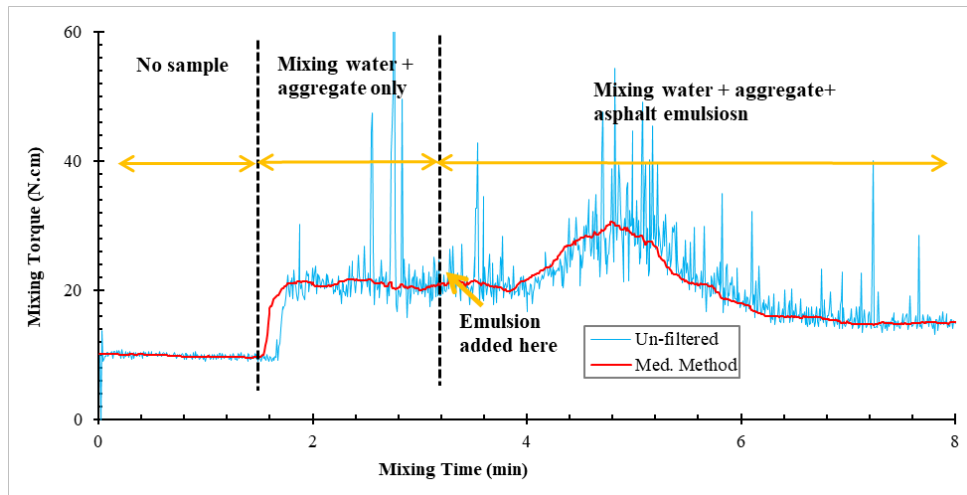


Fig. 2. Schematic of the testing procedure used and examples of the filtered vs. unfiltered results

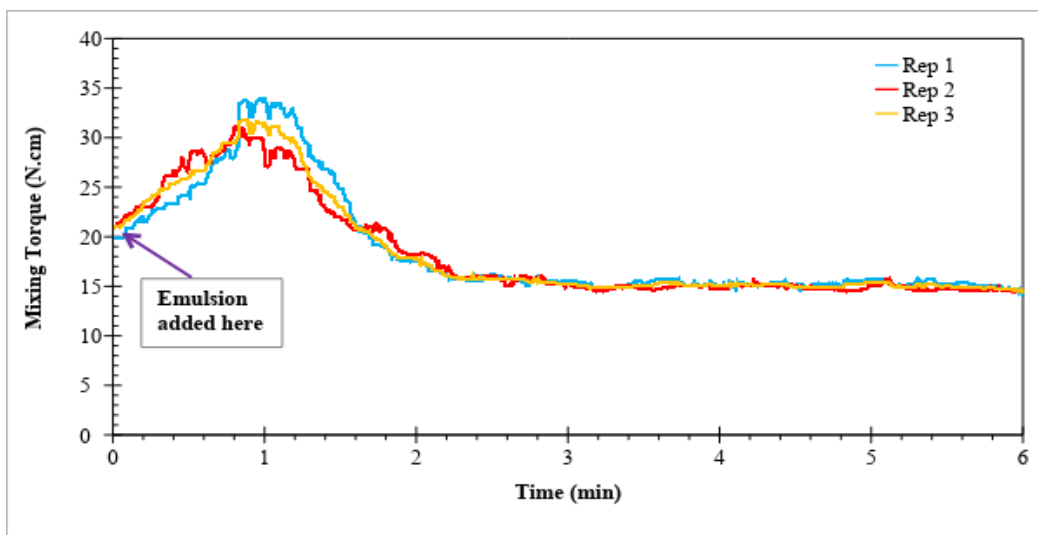


Fig. 3. Examples of the results of three replicates

IV. RESULTS

A. Minimum and Maximum Allowable Water Contents from Current Test Methods

The minimum water required to mitigate premature breaking and maximum water content to prevent segregation were determined with the Hand Mixing Test and Segregation Test. The results are presented in Fig.4. The results show that gradation appears to have little effect on maximum and minimum mixing water, irrespective of the emulsion type used. Emulsion type appears to have a slight effect on the maximum mixing water content. The amount of water content exceeding 10 times the amount of water needed to reach the SSD condition (10SSD) is more likely to result in segregation for the emulsion type used.

The minimum mixing water content appears to be significantly influenced by the type and chemistry of the emulsion used for a given gradation. For cationic emulsions, the minimum water

content is 7 SSD for both the neat (CSS-1H) and latex (CSS-1HL) modified emulsion. The effects of latex modification appear to have minimal effect on the minimum mixing water content. The anionic emulsions had a minimum mixing water of 5 SSD. In summary, the minimum water content to prevent insufficient mixing time is influenced by the chemistry (cationic or anionic emulsion) with cationic emulsion requiring higher amount of water than anionic emulsions for a given gradation. These findings are well in-line with the trends that have been reported in the literature [6 -11].

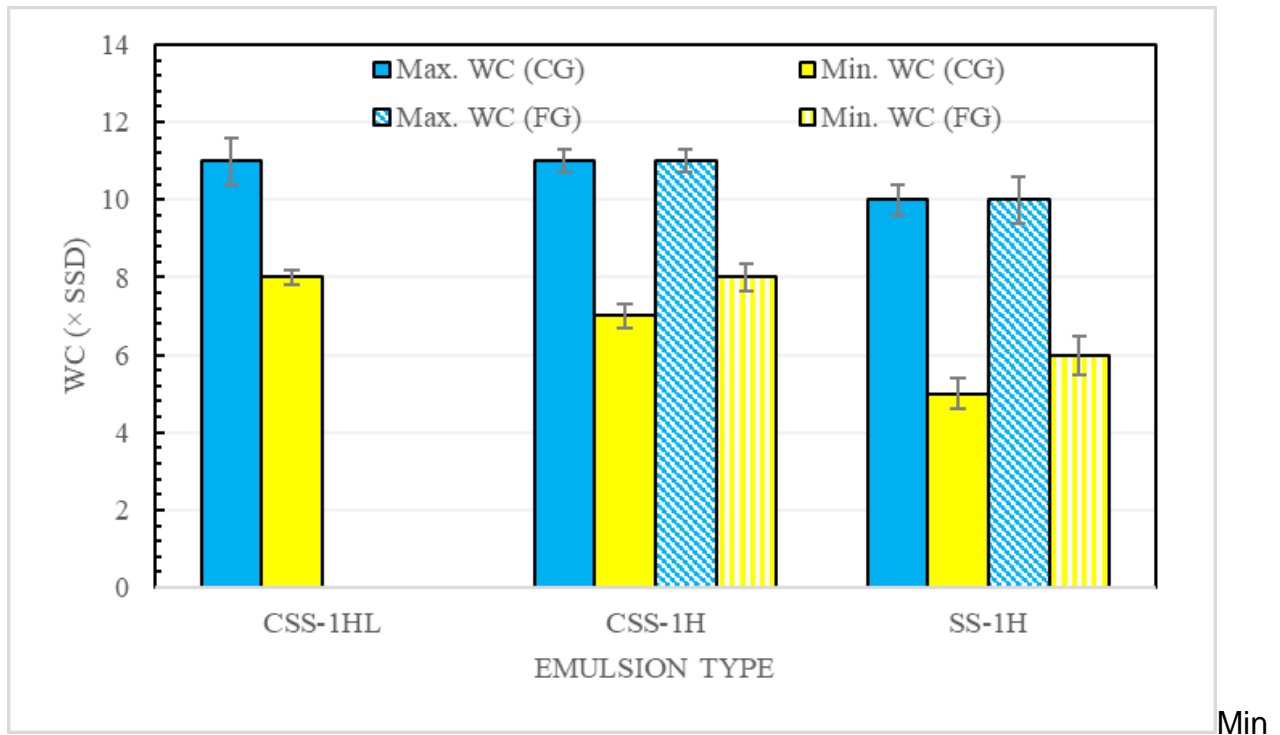


Fig. 4.

and Max Water Content Allowed.

B. Minimum and Maximum Allowable Water Contents Measured with the AMT

The results of the minimum and maximum water contents from the Hand Mixing and Segregation Tests presented in Section IV (A) were used to evaluate the suitability of the AMT in determining the workability of slurry surfacing mixtures. Samples for the AMT were prepared at three mixing water contents: (1) water content below the minimum allowed water content determined from the Hand Mixing Test (4SSD) (2) Optimum mixing water content which gave good workability (8SSD), and (3) High water content exceeding the maximum allowed water level (16SSD).

The results for the mixes with insufficient mixing time prepared at 4 SSD are presented in Fig.5. All mixes, irrespective of emulsion or gradation type, prepared with the water content below 5 SSD experienced premature breaking before a mixing time of three minutes could be achieved, when tested with the Hand Mixing Test. The results in Fig.5 clearly show that the AMT is sensitive to emulsion type and gradation when samples with insufficient mixing time were prepared. Samples made with the coarse gradation (CG) show a high mixing torque than those made with the fine

gradation (FG). This observation is in-line with the results presented in Fig. 5 which show that sample made with fine gradation has a lower minimum water content or requires less mixing water for a given workability than sample made with the coarse gradation.

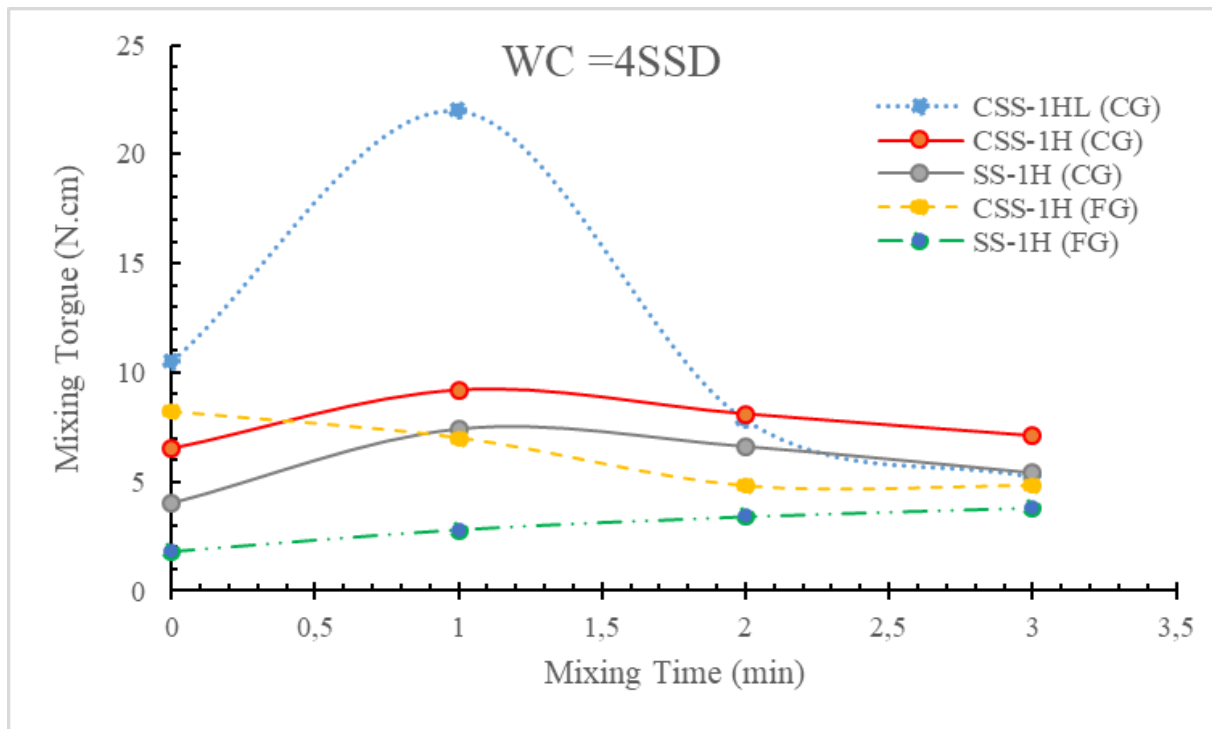


Fig. 5. AMT results for mixtures without sufficient mixing time (4 SSD)

The results also show that the AMT is more sensitive to emulsion type than the results of the Hand Mixing Test presented in Fig.4. Mixes made with the latex modified emulsion (CSS-1HL) had the highest torque (or mixture stiffness) at one minute of mixing, followed by the CSS-1H and then the anionic SS-1H, which had the lowest mixing torque. All mixes experienced premature breaking of the emulsion within the first one minute. The value of the mixing torque ranged from 22 to 6 N.cm for the coarse gradation and 6 to 3 N.cm for the fine gradation at one minute of mixing time. At three minutes of mixing time, the results ranged from 5 to 5.8 N.cm for the coarse gradation and 4.4 to 4.8 N.cm for the fine gradation.

The results show that the stiffness of the mixture, as indicated by the mixing torque, does not remain high or continue to increase with time as breaking progresses as inferred to in the literature [4]. It appears that the stiffness of the mixture or mixing torque decreases after the mixture has gone through the breaking process. The reduction in the mixing torque after the breaking of the emulsions can be attributed to the extra lubrication of the aggregate particles from the water that is “freed up” from the emulsion [6]. The results indicate that the torque value at one minute of mixing time can be a potential indicator of mixtures experiencing premature breaking. However, the AMT alone cannot be used to identify mixes with insufficient mixing time because the slurry surfacing mixtures are highly dependent on the chemical nature of the bitumen emulsions. The fact the mixing torque during

breaking ranges from 4.4 to 22 N.cm depending on gradation and emulsion used, at different mixing times, makes it a challenge to specify the torque value or mixture viscosity or stiffness as a sole parameter for identifying mixes with insufficient mixing time as suggested by others [4].

The results for mixes prepared with optimum water content or good workability with water amount of 8SSD are presented in Fig.6. All mixes prepared with 8SSD water content had a creamy homogenous consistency and a mixing time of over three minutes in the Hand Mixing Test. The presented results again show that the AMT is sensitive to emulsion type and gradation. Cationic emulsions show a higher mixing torque than anionic emulsions, and the coarse gradation show a higher mixing torque than the fine gradation. The torque level for mixes with good workability remained fairly constant from zero to three minutes of mixing time and beyond, with the exception of mixtures prepared with the latex modified CSS-1HL emulsion.

Mixtures prepared with the CCS-1HL emulsion showed a slight peak at one-minute mixing time of 13 N.cm and then the torque decreased to a constant level of 7.6 N.cm. This probably explained why the mixing time of mixtures with modified emulsions is determine at two minutes of mixing time. For unmodified emulsions, the mixing torque ranged from 5.9 to 7.6 N.cm for the coarse gradation and 2.4 to 3.7 N.cm for the fine gradation at three minutes of mixing time. The results presented appear to indicate that if the AMT is to be used for determining workability at three minutes of mixing time, different criteria may be required for different gradations.

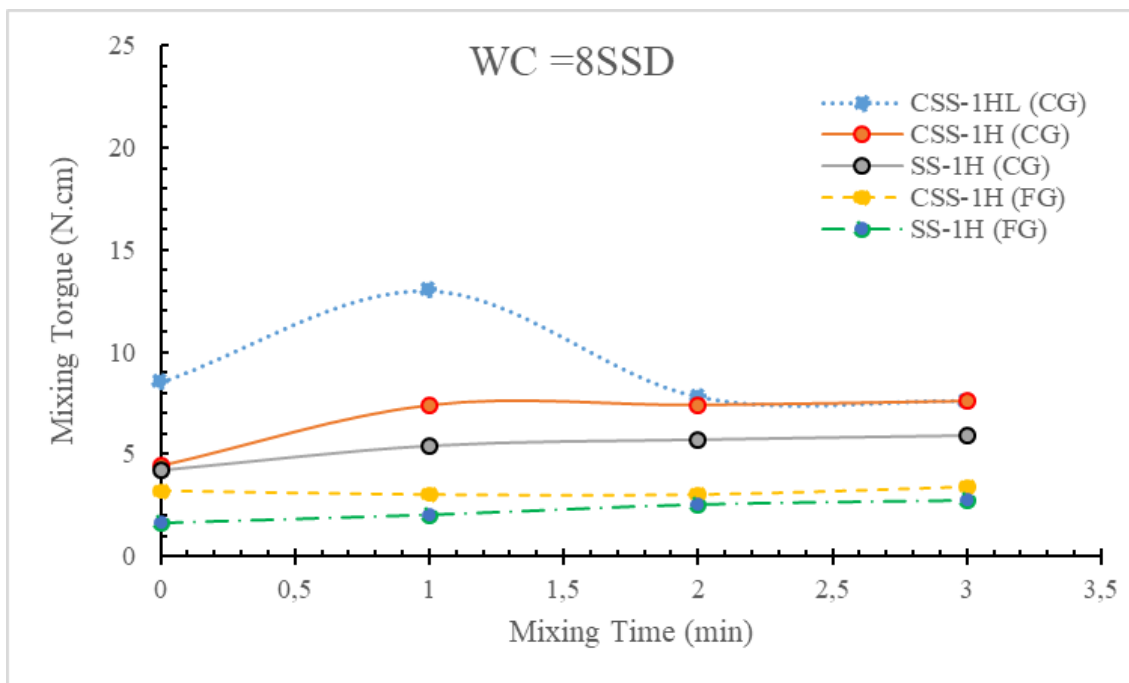


Fig. 6. AMT results for mixtures with sufficient mixing time and good workability (8 SSD)

The results for samples with severe segregation prepared with a water content of 16 SSD are presented in Fig.7. The results of the Segregation Test showed that all mixtures prepared with a water content exceeding 10 SSD experienced severe segregation.

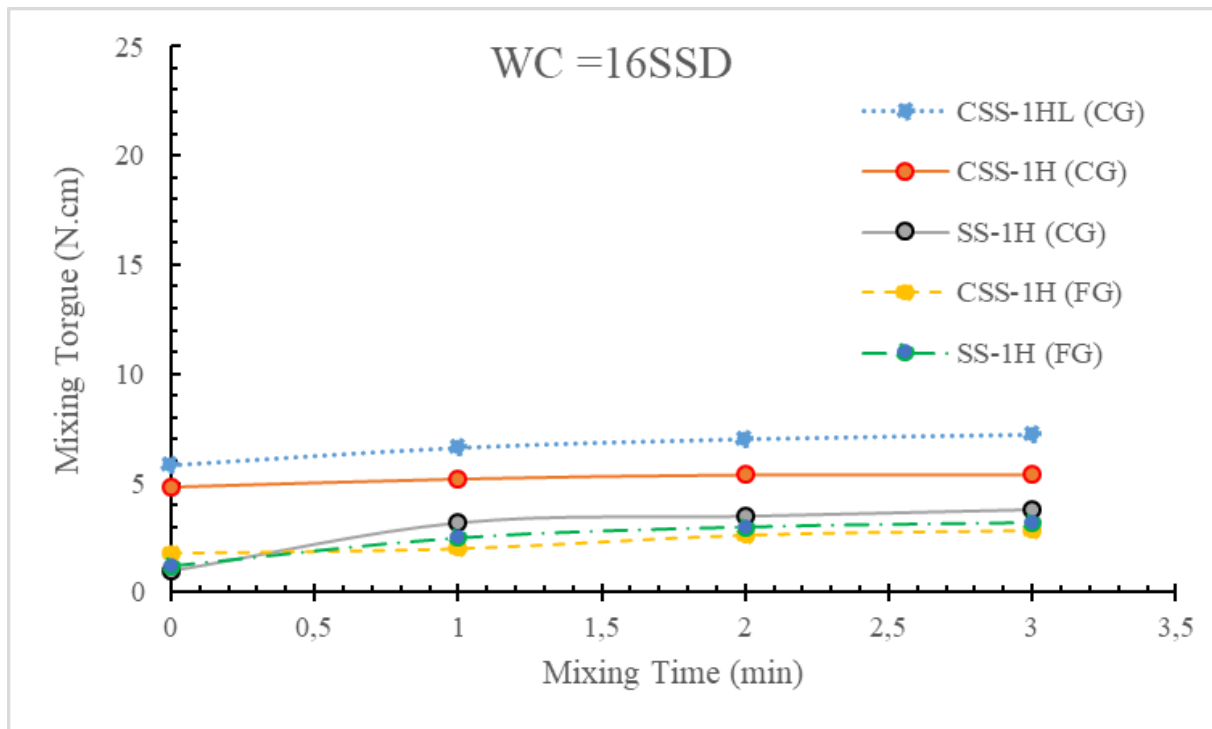


Fig. 7. AMT results for mixtures experiencing severe segregation (16 SSD)

The results presented show that the mixing torque for mixture experiencing segregation is fairly constant from zero to three minutes of mixing. However, the value of the mixing torque is also dependent on the type of emulsion and gradation used. The torque value ranged from 3.8 to 7.2 N.cm for coarse gradation and 2.8 to 3.2 N.cm for fine gradation. Again, cationic emulsions experience high mixing torque than anionic emulsions irrespective of the aggregate gradation. The latex modified emulsions also showed the highest torque compared to unmodified emulsions. It should be noted that the results for the CCS-1HL (CG), CSS-1H (FG) and SS-1H (FG) for both 8 SSD and 16 SSD water content are almost the same at three minutes of mixing time. Thus, it appears that the AMT used was unable to clearly differentiate between mixes with good workability and those experiencing segregation at three minutes of mixing time.

The results of the mixing torque for all mixes at one and three mixing times are presented in Fig.8 for comparison. Current specification requires workability to be evaluated at three minutes (or two minute for micro-surfacing). There is also a general perception that the stiffness of slurry surfacing mixes increases with time as a result of the breaking of the emulsion. Another assumption is that mixture experiencing severe segregation have “very low” mixing torque value or stiffness compared to those with good workability and insufficient mixing time.

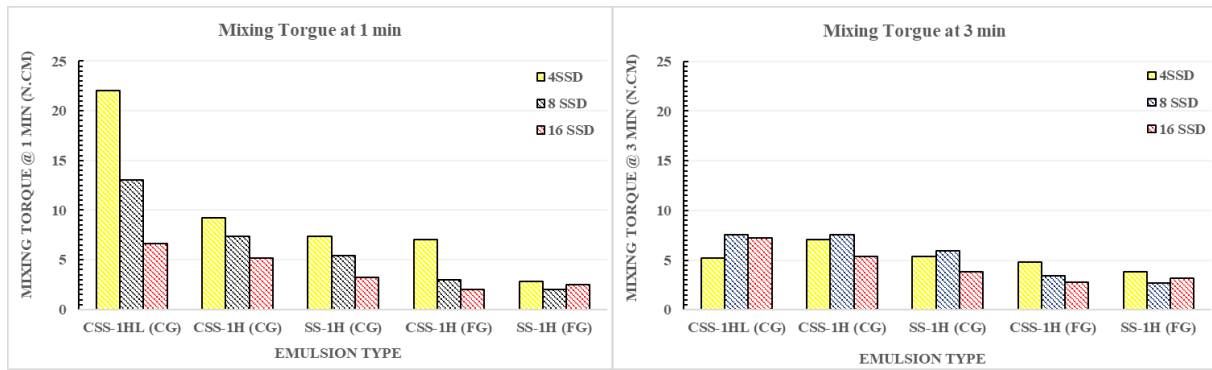


Fig. 8. Mixing Torque Value of different mixtures at one and three minutes of mixing time

The results show that the mixture stiffness as represented by the mixing torque value does not increase after breaking but rather decreases with time for the emulsion-aggregate combination used. This implies the criteria of using the torque value to identify mixes with insufficient mixing time at three minutes of mixing time could be misleading if used without supplementary subjective information from the visual observation of the mixture during the testing period. It can also be noted that all emulsion type gave similar mixing torque values at three minutes of mixing. This makes it difficult to differentiate between mixes with insufficient mixing time, mixes with good workability and mixes experiencing segregation if the mixing torque value at three minutes of mixing time is used as the evaluation criteria. Therefore, the AMT in its current form is not suitable for determining the workability of slurry surfacing mixtures, as there is a high variability between the mixing torques of mixtures with insufficient mixing time (4SSD). The results also show that the test cannot clearly differentiate between mixtures with good workability (8SSD) from mixtures experiencing severe segregation (16SSD) at three minutes of mixing time.

I. CONCLUSION

The main objective of this study was to establish if the AMT can be used to determine the workability parameters of slurry surfacing systems. The AMT has been reported and investigated in the literature as a potentially more objective test compared to the Hand Mixing Test, Split-Cup Test and Consistency Test currently used, which are highly depended on the experience of the operator. The following conclusion were drawn from the findings of this study:

- i. Mixing water amount below 5 times the amount of water required to reach the SSD (5SSD) condition of the aggregate resulted in mixes with insufficient mixing time, while mixture prepared with water amount more than 10 SSD value resulted in segregation for all emulsion, aggregate and gradation types used in this study. This information was determined using the Hand Mixing Test and Segregation currently specified in ISSA TB 143/105
- ii. The results of the AMT test showed that:

- The workability of slurry surfacing mixtures is mainly influenced by the chemistry of the bitumen emulsions, mixing water content, and aggregate gradation. Mixtures prepared with different emulsion types exhibited unique mixing torque versus time curves at the same mixing water content, besides being classified in the same category by the Hand Mixing Test (ISSA TB 113) and Segregation Test (ISSA TB 111).
- The mixing torque decreases when the mixture goes through the breaking and setting process during the 10 minutes of mixing time used in this study. Mixtures made with cationic emulsions showed high mixing torques than their anionic counterpart for a given gradation. In addition, latex modified emulsions showed a high mixing torque than their unmodified equivalent. Mixtures with coarse gradation had high mixing torques compared to mixtures with fine gradation.
- While the results of the AMT helped to understand the complex behaviour of slurry surfacing systems in their fresh state, the AMT however, is not recommended for evaluating the workability of slurry surfacing mixes in its current state. High variability (about 150% difference) between the mixing torques of mixtures with insufficient mixing time (4SSD) was observed. The results also show that the test cannot clearly differentiate between mixtures with good workability (8SSD) from mixtures experiencing severe segregation (16 SSD) at three minutes of mixing time (percent difference of 5% at times), especially those made with fine aggregates.

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