Performance evaluation and behavior of microsurfacing with recycled materials

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ABSTRACT

Road networks play a vital role in the development of country's economy. It is necessary to develop new technologies to improve the performance and safety of the roads. Added to that, it is necessary to enhance the evolution of the roadways over time in terms of maintaining its surface while respecting the challenges of sustainable development.
Microsurfacing is one of the techniques used to satisfy these challenges. However, there is very little information on the evolution and behavior of the product on short and long term, and there is no information on the use of recycled materials in the latter. In this context, this study aims to study and improve the performance of mixtures of microsurfacing with recycled materials.
After the development of an adapted accelerated aging method on Microsurfacing, materials were prepared in lab with reclaimed asphalt pavement (RAP) and with recycled asphalt shingles. It was shown that it's possible to prepare microsurfacing with 100% RAP while respecting all International Slurry Surfacing Association (ISSA) standards.
The results have shown that the filler's characteristics have a big impact on the rutting resistance of those mixes.
Procedures were developed during this project to measure the water sensitivity of the mixtures and their behavior over time.

Keywords: Adhesion, Durability, In-situ Recycling, Performance based standards, Reclaimed asphalt pavement (RAP) Recycling

Performance Evaluation and Behavior of Microsurfacing with Recycled Materials

1. INTRODUCTION

Road traffic, budget deficits as well as climatic rigors have an important impact on the behavior of materials of pavements and represent the main factors influencing the sustainability of roads.
Within some countries such as Canada and to a lesser extent, France, pavements undergo significant changes in thermal amplitudes and are therefore subjected to the risk of thermal cracking at low temperatures, or permanent deformation (rutting phenomenon) by high temperature bitumen softening.
These phenomena are accentuated by the increasingly traffic and its aggressiveness, which have intensified degradations to the pavements structures. A lack of maintenance may accelerate the progression of degradations, which, if they exceed the acceptable limits, require road construction companies to use extremely expensive rehabilitation techniques to restore the road's original properties. It is essential to ensure users a safe road network, in taking into consideration the above observations, especially regarding the choice of maintenance techniques[2].
Nowadays, several maintenance techniques are used, and among them micro-surfacing systems currently occupy a prominent place with 40 million m^2 in 2006 in France [14]. In Canada and in the USA, an average of 100 lane-km is covered in every Provinces / States with Microsurfacing each year [1]. These structures are set to provide good adherence and as applicable, to waterproof supports.
The principle of micro-surfacing is to mix aggregates (well-defined granular skeleton) with a modified bitumen emulsion, and the rupture is controlled by the addition of a breaking regulating agent (typically lime or cement).They can satisfy a variety of road construction needs.
Although the technique of Microsurfacing has proved that it works, that it's a safe technique and and it gives a comfortable surface, several issues and aspects remain to be studied and innovations are possible in this area.
Micro surfacing is a cold technique that requires little energies and time to implement. The use of recycled asphalt concrete is an important point of management for sustainable development, through the mastery of the environmental impact. In addition, it allows looking for high performances and reduced usage of aggregate quarries[3].
In this respect, the present study is part of a larger thesis work aiming at establishing a formulation of Microsurfacing made with 100% recycled asphalt materials and evaluating its behavior according to the tests imposed by the International Slurry Surfacing Association (ISSA).

2. Literature Review

Few studies exist on the incorporation of reclaimed materials in the micro-surfacing's mixtures. Studies have shown that it is possible to manufacture a Microsurfacing with only recycled bituminous materials, like Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS), (100% RA+12.5% asphalt emulsion +10% water) and the limit of adding asphalt shingles (RAS) of different compositions was 17% with virgin aggregates (17% RAS + 80% virgin aggregates +12.5% asphalt emulsion, +10% water) and by 10% if the rest of the aggregate skeleton is composed of recycled aggregates (10% + 90% RAP RAS). Table 1 shows whether the complied to the standardized ISSA tests. The various ISSA tests for Microsurfacing are detailed in the following paragraphs [9].

Table 1: Summary of test results with various blends of Reclaimed Asphalt pavement (RAP), Recycled Asphalt Shingles (RAS) and virgin aggregates with comparison to ISSA standard (Robati et al. 2013)

Micro-surfacing mixtures with different blends	Cohesion Test		Wet Track Abrasion Test		Displacement Test	
	30-min	60-min	1-Hour	6-Day	Lateral	Vertical
First Phase of Study						
100% Agg	√	√	√	√	√	√
50% RAP/50% Agg	√	√	√	√	√	√
100% RAP	√	√	√	√	√	√
10% RAS/90% Agg	√	√	√	√	√	√
17% RAS/83% Agg	√	√	√	√	√	√
25% RAS/75% Agg	X	X	√	√	X	X
33% RAS/67% Agg	X	X	/	/	X	X
Second Phase of Study						
100% RAP	√	√	√	√	√	√
10% RAS/90% RAP	√	√	√	√	√	√
17% RAS/83% RAP	X	X	√	√	X	X
25% RAS/75% RAP	X	X	√	√	X	X

√ : Respects the ISSA limit, X : Does Not Respect ISSA limit, / : Not-tested.

Research had also revealed that the fillers content appears to be the most important parameter to obtain the optimum mechanical performance and especially in the manufacture of Microsurfacing with recycled materials because they do not contain enough filler to form the mastic which allows better cohesion of product. Other studies have demonstrated that the addition of filler helps to improve several parameters such as[8]:

- The consistency (stiffening effect of the filler) resulting in a decrease in penetrability at 25° C;
- The viscosity at room temperature;
- Elastic properties at high temperature;
- The ring and ball softening point.

3. Objectives

This study is aiming at experimentally improving performances and behavior of Microsurfacing mixes made with 100% recycled asphalt materials, more precisely, it will be necessary to:

- Assess optimum emulsion content,
- Assess the effect of filler content on the cohesion of micro-surfacing containing a large amount of reclaimed asphalt pavement,
- Validate mixtures produced by the tests of ISSA.

4. Methodology

4.1 Choice of materials and composition of micro-surfacing

For this study, different types of material were used. The reclaimed asphalt pavements (RA) are from a quarry near Montreal, Quebec (Canada). Granularity of RA is between 0-5 mm. They contain about 5% bitumen content in mass. The reclaimed asphalt are mixed and separated according to the different diameters of the sieve in order to ensure a good graduation for all mixtures.
Three types of emulsions were used to prepare mixtures in this study:

- The first type of emulsified asphalt used is a CQS-1HP which is a cationic quick setting polymer modified asphalt emulsion, with 65% bituminous binder and 35% aqueous phase. The table 2 below shows the different characteristics of the emulsion provided by Mc Asphalt Engineering Services (Table 2),

- The second type of emulsified asphalt is named "low penetration" cationic bitumen. It is an European emulsion modified by SBS polymer and provided by Latexfalt BV company in Netherland (Table 2),

- The third type of emulsion is an Anionic emulsion provided by Mac Asphalt.

Table 2: CQH-1HP and low penetration asphalt emulsion properties from suppliers

Asphalt emulsion name	Type of base binder	Asphaltene (%)	Acid Type	Type of Polymer	Penetration	Residue by distillation	pH of emulsion
CQS-1HP	PG 64-22	14.7	Phosphoric	SBR latex	60 dmm	65.1 %	3.0
Low penetration	PG 70-22	20.6	Hydrochloric	Linear SBS	36 dmm	57%	2.2

4.2 Experimental process

The mixtures of the Microsurfacing were based on the outcome of the work of Robati et al. (2013), according to the standards of the ISSA (International Slurry Surfacing Association). The basic formula consists of virgin aggregates (mixing 100% virgin aggregates), 12% in emulsion content, water content 10% and 1% of cement. The base of the formula curve was inserted in the granular curve limits (0 to 5mm) ISSA to determine its granularity. Starting from the granular curve limits (0 to 5 mm) ISSA standard, three types of formulas were determined according to their classification within the granular curve limits (0 to 5 mm). These are the mixtures: dense-graded DG (reference mixture) centered on the spindle, the coarse-graded CG mixture at the bottom of dense-graded DG mixing and fine-graded FG mixture situated below the reference mixture (Figure 3).

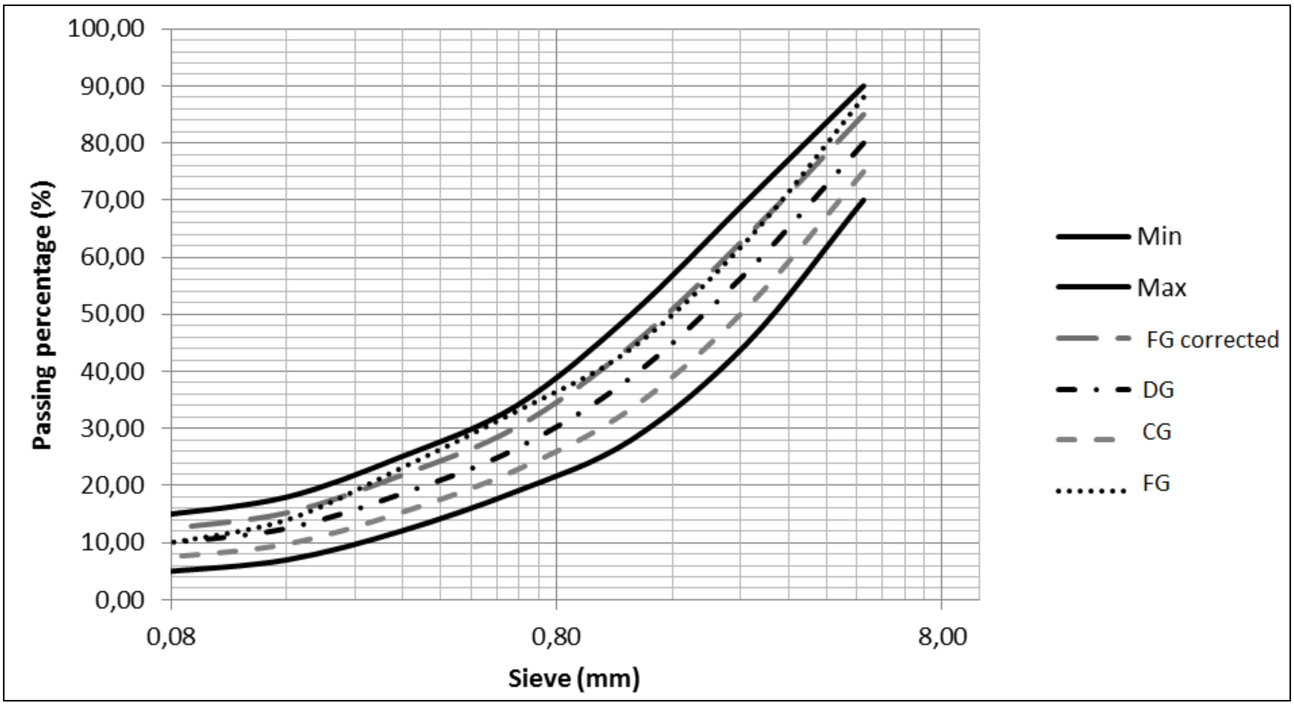

Figure 1: Upper, Lower and middle aggregate gradation curves (0-5 mm size)

In Figure 3, modification is observed in the particle size curve of the basic formula (FG corrected) relative to the DF curve. The correction of the error was made by considering the average of the curve Max and dense-grated mixtures. The dense-graded DG mixture was determined by averaging the Max and Min curves. The coarse-graded mixture was determined by averaging the graded-grade and Min curves. These average percentages of passing will be converted into retained percent in sieves and then the masses for 500g mixture of micros-surfacing as shown in table.

Table 3: Passing and refusal percentage per sieve size for different mixtures

Formula Dense-Graded			**Formula Coarse-Graded**			**Formula Fine-Graded**		
% Passing	**% retained per sieve**	**Mass for 500 g**	**% Passing**	**% retained per sieve**	**Mass for 500 g**	**% Passing**	**% retained per sieve**	**Mass for 500 g**
80	20	100,0	75	25	125,0	85,0	15	75,0
58	23	112,5	51	24	118,8	64	21	106,3
39	19	92,5	34	18	88,8	45	19	96,3
27	13	62,5	23	11	53,8	30	14	71,3
19	80	40,0	15	7,5	37,5	22	8,5	42,5
13	6,0	30,0	9.8	5,5	27,5	15	6,5	32,5
10	2,5	12,5	7,5	2,3	11,3	12	2,8	13,8
0	10	50,0	0	7,5	37,5	0	12,5	62,5

To define the emulsion content in the mix design, RA in this study is considered as a black rock because Microsurfacing is a cold technique and the considered binder's RA cannot be melted at room temperature in short term and it can be affected in long term. In this study, there are total 9 mixtures that come from three different granular mixtures (dense, fine and coarse) and three different emulsion contents and it is aimed at the validation of those mixes according to the criteria of the ISSA (Cohesion test, Wet track abrasion test, Multilayer loaded wheel test). For each emulsion content, minimum and maximum (Table 4) values have been chosen to evaluate the influence of the variation in the content. The water content and the percentage of cement are constant (11% water and 1% of cement). Table 4 presents the different formulations.

Table 4: Microsurfacing mixtures

Formula	Dense-Graded	Coarse-Graded	Fine-Graded
weight percentage %			
RA	100	100	100
Emulsion	11.5-12-12.5	11-11.5-12	10.5-11-11.5
Water	11	11	11
Cement	1	1	1

The reference will be shown once the fabrication of Microsurfacing with virgin aggregates is completed. The formulations used in this experimental process are tested by the cohesion tests, results with respect to this will be presented in the result section.

4.3 Validation Tests

The different mixtures need to be validated with tests for Microsurfacing in accordance with the standards of the ISSA. The tests are the Cohesion test (ISSA TB-139)[5], the Wet Abrasion test (ISSA TB-100)[6] and the Multilayer loaded wheel test (ISSA TB-147) [7]

.**Modified cohesion test ISSA TB 139 [5]:**

The cohesion test is used to classify Microsurfacing mixtures to slow or fast setting systems. It can also be used to establish a suitable binder emulsion water combination which is obtained from results after 30 min and 60 min of curing at room temperature 25°C (77°F). The minimum values required are 2 kg.m for a 30 minutes cure test and 20 kg.m for a 60 minutes cure time (Figure 2).

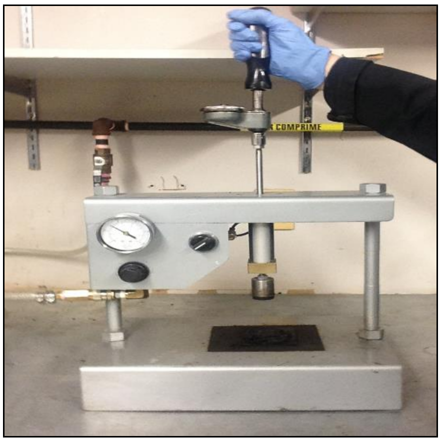

Figure 2: Modified cohesion tester

Wet Track Abrasion Test ISSA TB 100 [6]:

The test consists in determining the percentage loss of materials in asphalt mixtures in wet abrasion conditions. The test is performed after heating the sample at 60° C for 24 hours. The sample is immersed in water for one hour at room temperature. Once the test performed, the sample is washed and placed in an oven at 60° C to dry. The difference in weight is calculated between the weight after test and the weight measured before placing sample in water corresponds to the loss of the amount of abrasion mixture. Wet track abrasion test were performed on 1 hour soaked sample to determine susceptibility to moisture exposure (Figure 3).

Figure 3: Wet track abrasion tester

Multilayer Loaded Wheel test Vertical and Lateral Displacement WTAT ISSA TB 147 [7]:

Loaded wheel test, described by the standard ISSA TB 147 allows characterizing the resistance of mixtures against rutting (and bleeding) under heavy traffic. The test WTAT defines the minimum amount necessary for preventing deformation of the asphalt binder by comparing the results of several samples containing different percentages of asphalt binder content. The the sample is placed in oven 24 hours to 60° C and 24 hours at room temperature. 1000 cycles are carried out with a change of 56.7kg (ISSA) (Figure 4).

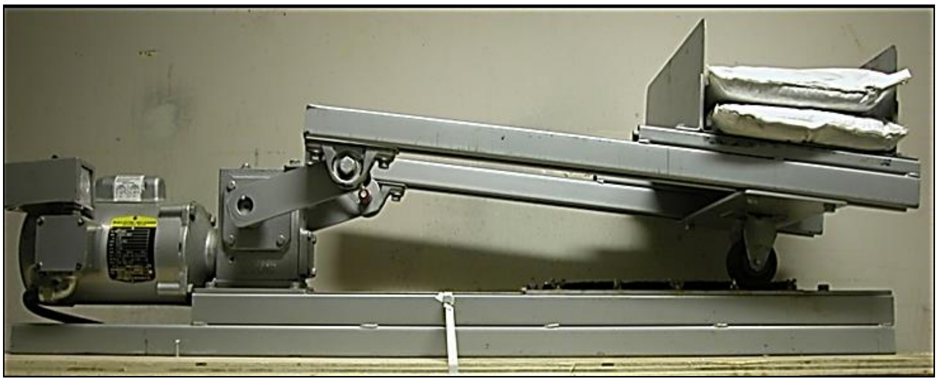

Figure 4: loaded wheel tester

5. Results

Analysis of the results were divided into three parts:

- Results of the cohesion test for reference Microsurfacing made with virgin aggregates
- Secondly, the interpretation that was used to assess the behavior of the 9 mixtures following the completion of the various tests, which identified the different results
- And the third part which was to improve the results of the selected mixture

Analysis of all mixtures:

This first part of this section is to show the results of cohesion tests on Microsurfacing with virgin aggregates. The 3 mixtures were manufactured from three gradations(dense, coarse and fine). Tests are done after 30 min and 60 min of cure time. The results obtained are satisfactory: All mixtures verify the Min limit of ISSA which are 12 kg.cm for 30 min and 20 kg.cm for 60 min respectively. From this result, products and formulation used in this study are adapted for manufacturing Microsurfacing.

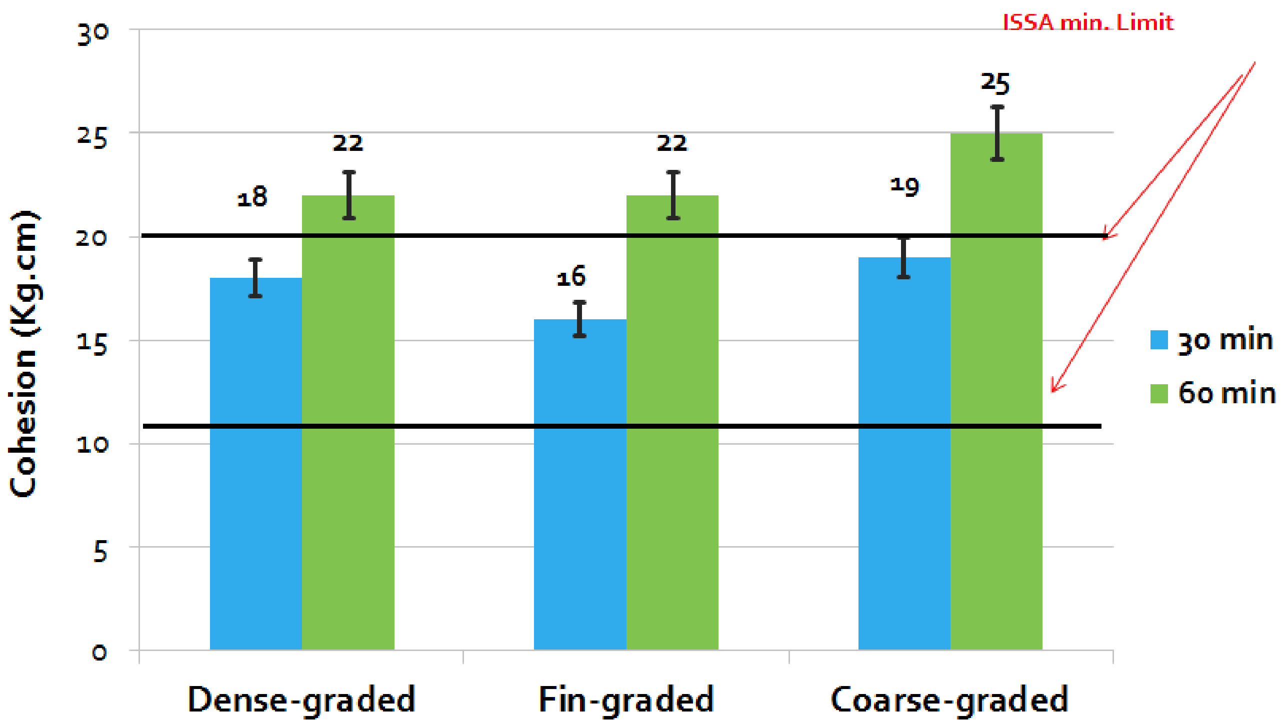

Figure 5: Results of cohesion test for Microsurfacing with virigin aggregates

The second result of this section is about Microsurfacing done with 100% RA: Table 5 shows the influence of the granularity on the performance of micro-surfacing mixtures. The mixtures are numbered from 1 to 9. These numbers are used to differentiate the various mixtures for each formula according to bitumen emulsion content.
For the cohesion test at 30 minutes, the results are approximately the same and do not detect a granularity effect: Average 10.6 g.cm (σ = 1.8) for 30 min, similarly, all 60 min cohesion results are roughly substantially equal: average of 12.5 g.cm (σ = 2.1).
Moreover, the cohesion at 60 min shows no conclusive results because all the values are less than 2 Kg.m.
For the abrasion test, the results show that Fine-Graded mixtures do not satisfy the acceptance limits for all binder contents considered.
The Dense-Graded mixtures and Coarse-Graded, in turn, exhibit good results but are, however, influenced by the emulsion content. Thus, it is observed that the Dense-Graded mixtures 1 and Dense-Graded 8 show excellent results. We can conclude that the abrasion test is influenced by the granularity and the binder content.
For the test of horizontal and vertical displacement, the results are satisfactory, except the Dense-Graded mixture 2 and the Graded-Coarse mixture 7, which means that the granularity is not a very marked influence on tests of displacement.
The analysis of performance tests obtained with the various new mixtures of granularity show that the mixture 9 (Coarse-Graded) has the best performance.

Table 5: Results summary for all tests done on micro-surfacing

		Cohesion test		Abrasion test	Loaded Wheel test	
Formulas	**Binder emulsion content (%)**	**Cohesion test 30 min (>1.2kg.m)**	**Cohesion test 60 min(>2kg.m)**	**Limit max 807g**	**Lateral displaceme nt (<5%)**	**Vertical displaceme nt (<10%)**
Dense-Graded 1	11.5	7.9	12.9	300	-	-
Dense-Graded 2	12	10	13.9	414.5	7.5	11.2
Dense-Graded 3	12.5	12	12.8	438	3.4	8.7
Fine-Graded 4	11.5	12.8	15.3	974	4.1	1.5
Fine-Graded 5	11	8.2	8.2	1499	1.7	5.7
Fine-Graded 6	10.5	11.9	11.9	1849	3.7	0.3
Coarse-Graded 7	11	9.4	10.9	447	6.2	9.7
Coarse-Graded 8	11.5	11.8	12.1	155	1.9	9.09
Coarse-Graded 9	12	11.2	14.8	414.5	2.4	7.7

Given the satisfactory results of abrasion and displacements test of mixture 9, a more detailed study is conducted on this mixture in order to improve its poor cohesion.

Additional analysis on the mixture 9:

In this part of study, at first, by observing the behavior of mixture towards cohesion depending on time and type of emulsion, so 5 times of cohesion measures (30 min, 60 min, 24 (1440mn), 48 (2880mn) and 72 (4320mn) and different types of emulsion were taken into consideration. So, the nature of emulsion is changed to see the effect of emulsion type on results. The second aspect is to regenerate the aged bitumen of RA, so bitumen cleaner is introduced in order to see if it is possible to melt bitumen from RA., the below Table 6 results show the aged binder did not participate in mixtures.

Table 6: Results Summary of Cohesion tests done on mixture 9 using different type of emulsion

Time (min)	**Europeean emulsion**	**CQS-1HP emulsion**	**Europeean emulsion SBS+ BC**	**CQS-1HP emulsion + BC**	**Anionic emulsion**
30	11,2	7,2	7	10,1	7,2
60	14,8	7,8	8	10	9
1440	20	15,1	13,9	11,2	18,5
2880	21,9	16	-	-	20
4320	23	21	-	-	-

*BC: Bitumen Cleaner

Figure 7 shows that the cohesion values in conformity with ISSA requirements are obtained after 24 hours with the European emulsion modified by polymers, 48h for the Anionic emulsion and 72h for mixtures made with the CQS-1HP emulsion respectively. The results obtained with other emulsions do not conform to 72h. Therefore this shows that the European emulsion is suitable for the formulation of micro-surfacing using recycled asphalt and its cohesion is changing faster than other emulsion used in this study.

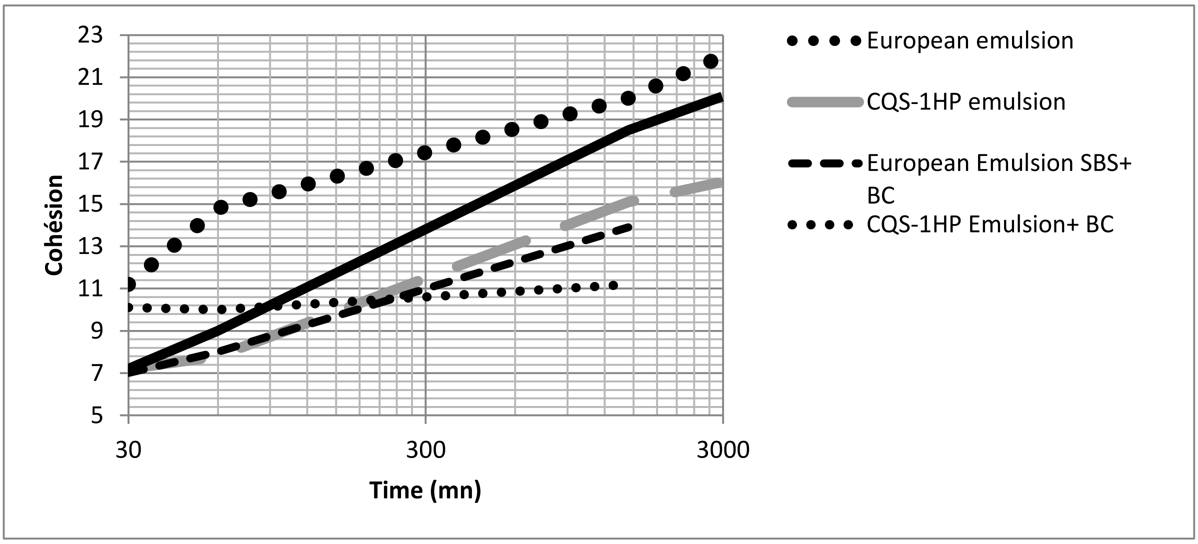

Figure 6: Effect of asphalt emulsion on cohesion test done on mixture 9 at different times

Secondly, in order to approach time requirements of the standard ISSA, a second study is conducted on European emulsion to reduce the time of cohesion. Thus, different cement contents ranging from 0.3% to 2.5% are used in table 7 results are shown below.

Table 7: Results summary of cohesion test done on mixture 9 (different cement's content)

Time (min)	1% cement+ Europeean emulsion	1.5% cement+ Europeean emulsion	2% cement	2.5% cement + Europeean emulsion	0.2% cement+ Europeean emulsion	0.3%cement + Europeean emulsion	0.5% cement + Europeean emulsion
30	11,2	9,8	9,7	9,3	10,5	10,8	11,2
60	14,8	13	11	13	11	12,5	14
1440	20,3	21	14,1	18	16,2	19,5	22,9
2880	21,5	21,9	17,3	18,2	22	20,6	16,8

Figure 8 shows that the cohesion values conforming to ISSA requirements are obtained more rapidly for low cement content of 0.3% to 1.5%. Among these blends, the best result is obtained at 1% and 1.5% cement.

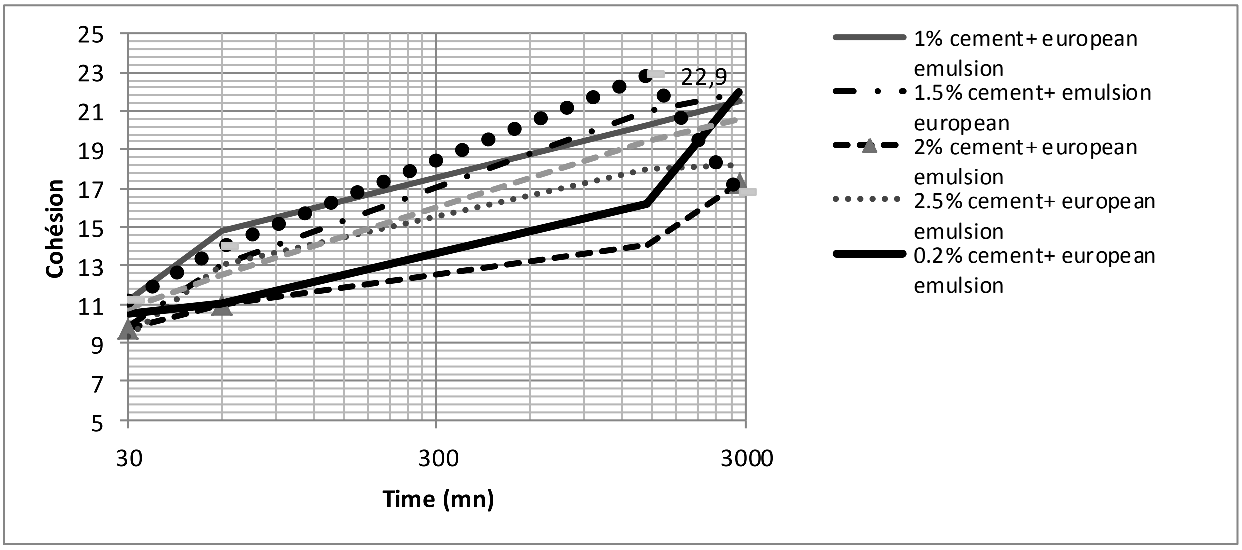

Figure 7: Evolution of cohesion test done on mixture 9 at many times using different cement's content

To better assess the aspect of cohesion of the Coarse-Graded mixture 9 (12% bitumen emulsion, 1% water and 1% cement), a cohesion test internally developed by colas has been achieved. The HILT cohesion test (HCT) evaluate the tensile strength and breaking time of Microsurfacing by measuring the time of sample's break.
This test allows us to get information about the start of the increase in cohesion. So, it can be used to classify Microsurfacing as either slow or fast setting systems. HCT test was performed on a reference mixture: Microsurfacing with virgin aggregates.

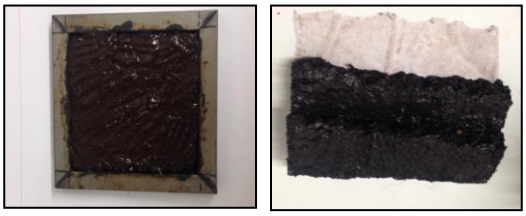

Figure 8: Hilt Test Cohesion

The results show a breaking time of 2 minutes 50 for Microsurfacing with virgin aggregates. This time defines the time it takes to open the traffic. The criteria of experience are not standardized. These HCT tests on recycled Microsurfacing gave results of 40 seconds to 30 minutes and 1 minutes 36 to 60 min respectively. These results demonstrate again that recycled Microsurfacing require a longer rest period before being open to traffic.

6. CONCLUSION

Many tests carried out on mixtures of Microsurfacing that have allowed evaluating the behavior of a Microsurfacing formulated with recycled asphalt materials and highlighting the difficulties in the implementation formulas. Aim of this study is to answer the problems of recycling without limitation in the recycled use rate. The results of abrasion and displacement tests have shown acceptable behaviors for all blends used. Cohesion problems are detected for all mixtures.
In order to improve the results of cohesion, various parameters were modified to reach the requirements of the tests imposed by the ISSA. The first consisted in estimating the influence of the type of emulsion and the time on the cohesion's behavior of Microsurfacing. Several cement contents were also used to analyze the effect of the cement on the cohesion of Microsurfacing mixtures. Improved results of cohesion tests was found after a longer testing time (from 24 hours) which allows to conclude that the opening time traffic for a Microsurfacing made with recycled materials is higher than mixes with fresh aggregates. The effect of some parameters on the performance of Microsurfacing made with recycled aggregates that were evaluated in this study are the granularity of the aggregates used, the nature of the bitumen emulsion and the breaking additive content (cement). However, all our mixtures require more time than the ISSA time specification to reach a good cohesion.

To conclude, results were shown that nature of emulsion can influence the behavior of Microsurfacing made with RA. So, it is important to adapt emulsion when working with RA because of different interaction between aged bitumen and binder's emulsion

In perspective, this study will be continued to try to improve the short term cohesion. Mixes with reduced cement content and with added virgin aggregates (increase the filler content) will be made. However, it should be noted that the use of reclaimed asphalt pavement requires a very good control of the granularity. Therefore, it seems appropriate to reflect on the different scientific and economic constraints in the use of recycled materials. It would be interesting to study the possibility of incorporating other recycled materials, and also the use of a rejuvenator which help in restoring the initial characteristics of the RA binder.

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