Early Stage Curing Characteristics of Partial Depth Cold Recycling

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ABSTRACT

The partial depth cold recycling process using asphalt emulsions (CIR) has been utilized in Canada for more than twenty years with great success. Over the last seven to eight years, another partial depth process utilizing expanded (foamed) asphalt cement has also been used.

The Cold In-place Recycled Expanded Asphalt Mix (CIREAM) process is the same as traditional CIR except for the delivery system of expanded asphalt cement. The original premise for this process was to minimize curing time prior to overlaying and provide an extended paving season. Over the last few years there have been field issues with severe raveling and potholing of the mat prior to the overlay being placed. These problems have been attributed to cool weather conditions during placement, rain occurring shortly after placement, or poor compaction due to the environmental conditions.

A laboratory study was initiated to evaluate the effects of various additives (such as Portland Cement, Hydrated Lime, WMA Additives and Anti-stripping Agents), the effect of various emulsion types, as well as moisture effect on raveling. The mixes were evaluated using ASTM D7196 “Standard Test Method – Raveling Test of Cold Mixed Bituminous Emulsion Samples” to determine the resistance of the cold mix to trafficking.

RÉSUMÉ

Le processus de recyclage à froid de profondeur partielle à l'aide d'émulsions de bitume (CIR) a été utilisé au Canada depuis plus de vingt ans avec un grand succès. Au cours des sept à huit dernières années, un autre processus de profondeur partielle utilisant le bitume expansé (mousse) a également été utilisé.

Le processus de recyclage à froid en place au bitume expansé (CIREAM) est le même que le CIR traditionnel sauf pour le système d’approvisionnement du bitume expansé. La prémisse originale pour ce processus était de minimiser le temps de séchage avant le resurfaçage et de fournir une saison prolongée de pavage. Au cours de ces dernières années, il y a eu des problèmes de terrain avec de l’arrachement sévère et des nids de poule sur la couche de revêtement avant que la couche de surface soit placée. Ces problèmes ont été attribués à des conditions météorologiques fraîches durant la pose : pluie peu de temps après la pose, ou compaction médiocre en raison des conditions environnementales.

Une étude en laboratoire a été lancée pour évaluer les effets de différents additifs (comme le ciment Portland, la chaux hydratée, les additifs WMA et les agents anti-désenrobage), l'effet de divers types d'émulsion, ainsi que les effets de l'humidité sur l’arrachement. Les mélanges ont été évalués selon ASTM D7196 «méthode standard – essai d’arrachement pour échantillons d’enrobés froids à l’émulsion de bitume» afin de déterminer la résistance de l’enrobé froid au trafic.

1.0 INTRODUCTION

The partial depth Cold In-place Recycling process using asphalt emulsions (CIR) has been utilized in Canada for more than twenty years with great success. The CIR process involves grinding up the existing Hot Mix Asphalt (HMA) pavement to a depth of up to 125 mm. The ground material is further processed to the proper size in a mobile crushing operation, asphalt cement (in the form of an emulsion) is added and mixed, then the blended material is laid back down and compacted to form a binder course layer. Typical recycling trains are shown in Figure 1. A new HMA surface is placed after the CIR mix has set, and the moisture and compaction requirements have been met. This typically occurs within 14 to 30 days.

Figure 1a. Single Unit Train

Figure 1b. Multi-unit Train

Figure 1. Typical Cold In-place Recycling Trains

Over the last seven to eight years, another CIR process has incorporated expanded (foamed) asphalt cement instead of an asphalt emulsion. This process is known as Cold In-place Recycled Expanded Asphalt Mix (CIREAM). In the CIREAM process, extremely hot (160°C plus) asphalt cement is pumped through an expansion chamber on the recycling machine where a small amount of water, (typically 1 to 3 percent) is injected causing the asphalt cement to foam. The foamed asphalt cement is mixed with the reclaimed asphalt pavement and the material is then laid and compacted to form a binder course layer. Figure 2 shows the typical CIREAM recycling train, which can also be utilized for CIR.

Figure 2. Cold In-place Recycled Expanded Asphalt Mix Train

2.0 BACKGROUND

Over the last few years, the use of CIREAM has become a major method used in the road rehabilitation process in the Province of Ontario. The Ministry of Transportation Ontario, as well as many counties and Municipalities, are routinely utilizing the process. The major selling point used to market CIREAM was that the expanded mix only needed two to three days of curing before the HMA overlay could be placed. The other selling point was that the process was less dependent on warm dry weather for placement, which would lead to an extended construction season for CIR [1].

When both the emulsion CIR and the CIREAM processes are used during the early or middle portion of the construction season, the mixes perform very well. It is during the later part of the construction season (September and October) that issues arise with the performance of CIREAM, prior to being covered with HMA. During the late season, mat deficiencies arise due to the cooler air temperatures combined with rain on the fresh CIREAM mat. The issues occur once the road is opened to traffic with severe raveling and large potholes developing in a very short period of time. The road conditions can be so severe that the expanded material is either overlaid with a skin coat of hot mix or removed by milling and filling with hot mix. This problem seems to be occurring much more frequently in the last two or three years with the CIREAM product. Figure 3 shows the severe road condition when CIREAM was placed and Figure 4 shows a CIR recycled road surface that is performing very well.

Figure 3. Cold In-place Recycled Expanded Asphalt Mix Failure shortly after Construction

Figure 4. Emulsion Cold In-Place Recycling Project in Good Condition shortly after Construction

Because of these costly issues, a laboratory study was initiated at McAsphalt Industries Limited to investigate this field problem. It was felt that a raveling test would be acceptable to evaluate the mixes in the laboratory during the early stages of their life. The abrasive force that the compacted specimen receives simulates the tire action of the traffic on a newly placed cold recycled surface. The raveling test was utilized with both CIR and CIREAM bituminous binders to determine if there were any differences in the amount of material lost after the test was performed. For the CIREAM mixes, PG 58-28 asphalt binder was selected while HF150M, HF150M(P), CSS-1 and CSS-1P emulsions were utilized for the CIR because they are the most common emulsions used by the industry in Canada.

The two additives (Portland Cement and Hydrated Lime) have been extensively used in Full Depth Reclamation (FDR), as well as partial depth recycling such as CIR and CIREAM. Warm mix asphalt additives and anti-stripping agents have been utilized both in the laboratory, as well as the field and it was thought that they should be added to the laboratory study to evaluate their effectiveness.

3.0 LABORATORY PROTOCOL

3.1 Overview

In order to evaluate this phenomenon occurring in the field, a laboratory study was initiated to duplicate the problem and try to develop a way of eliminating the raveling. To simulate the raveling occurring in the field, the raveling test as described in ASTM test method D7196 was used [2]. This test method measures the raveling resistance of field mixtures such as Reclaimed Asphalt Pavement (RAP) and bituminous binders by simulating the abrasion that occurs when a newly constructed road is returned to traffic.

The RAP material used in the study was from a stockpile that McAsphalt Engineering Services uses for all its research efforts related to foam and asphalt emulsion CIR and FDR. The material is from an actual CIR emulsion project and is very representative of a typical CIR candidate. Table 1 shows select properties of the various mix designs. The physical test data on the three designs are similar and should theoretically provide equivalent results in the field.

Table 1. Mix Design Properties

Properties/Liquid Used	**CSS-1**	**HF150M**	**PG 58-28**
Asphalt Residual Added, % (% Emulsion)	1.2 (1.8)	1.2 (1.8)	1.25
Bulk Relative Density (tonne/m³)	2.076	2.091	2.085
Maximum Relative Density (tonne/m³)	2.440	2.458	2.456
Air Voids (%)	14.9	14.9	15.1
Indirect Tensile Strength (ITS) Dry (kPa)	490.6	477.2	596.3
Indirect Tensile Strength (ITS) Wet (kPa)	434.5	405.7	508.4
Retained ITS (%)	88.6	85.0	85.2
Marshall Stability (Newtons @ 22°C)	23783	18100	25829
Flow Index (0.25 mm)	24.7	19.8	19.7

3.2 Test Method Summary

The raveling test can be used on samples of material taken from the field or from laboratory-prepared mixes. The mix is compacted in a gyratory compactor using a 150-mm mould and 20 gyrations. The proper amount of material is used to give a finished sample height of 70 ± 5 mm. Once compacted, the specimen is cured at the specified conditions for a designated period of time. Typical testing parameters used are curing at ambient laboratory conditions (20 to 24°C) for 4 hours ± 5 minutes. Some American states are specifying the raveling test for their CIR projects and use a testing temperature value of 10°C with a maximum of 2 percent loss [3, 4].

After curing for the proper length of time, the sample is weighed and placed in the abrasion machine where a rubber hose applies an abrasive force on the specimen for a preset time interval (typically 15 minutes) and the abraded loss of material is calculated. The typical setup of the raveling apparatus is shown in Figure 3 while Figure 4 shows a close-up of the test in progress.

Figure 3. Ravelling Test Apparatus

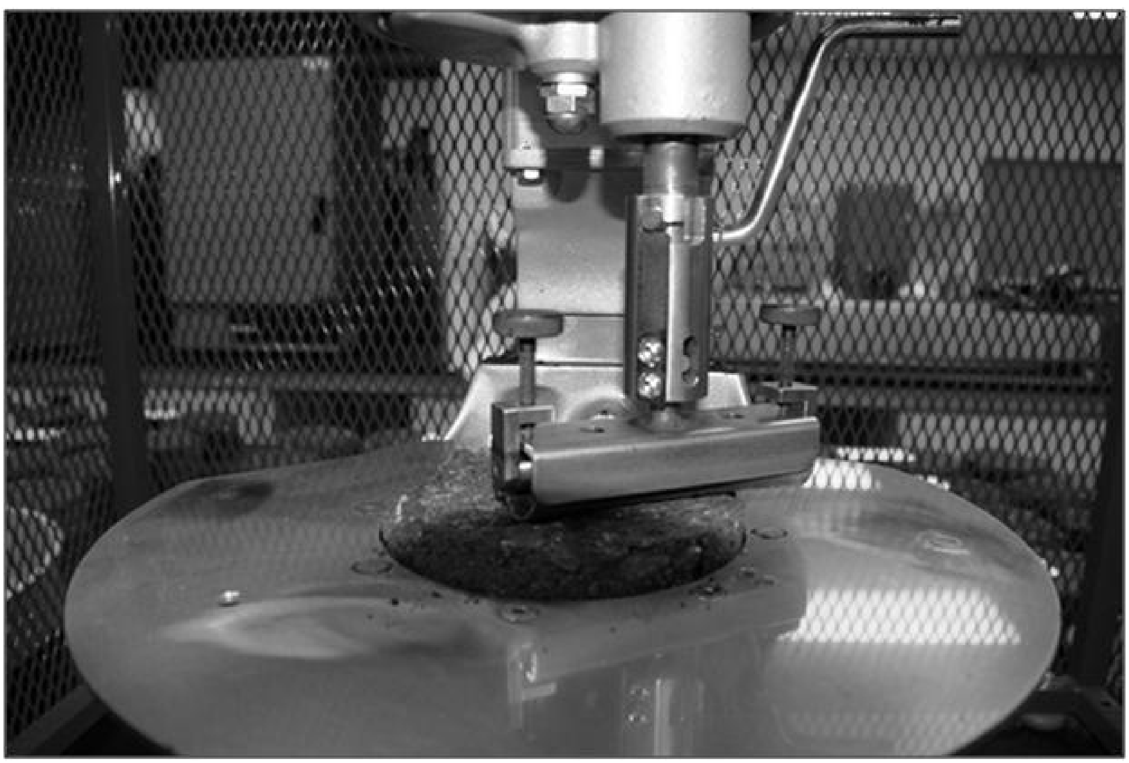

Figure 4. Close-up of Ravelling Test in Progress

3.3 Testing Performed

A number of different asphalt emulsions (CSS-1, CSS-1P, HF150M, and HF150M(P)) were used, as well as PG 58-28 asphalt cement for the foaming portion of the laboratory study. The additives used were Portland Cement, Hydrated Lime, Evotherm warm mix chemical, Adhere 7700 anti-stripping additive, and a Latex additive UP5000. The cement and hydrated lime were added at dosage rates of 0.5 and 1.0 percent by mass of the mix. The warm mix additive and the anti-stripping agent were added at a dosage rate of 0.5 percent of the asphalt cement. The latex additive was added to the mix at a dosage level of 1.0 percent. The quantity of asphalt emulsion used for the four emulsion mixes was 1.75 percent, while for the foam tests, the quantity of asphalt cement was 1.25 percent.

Initial trials were performed to determine the optimum sample size to achieve a compacted depth of 70 ± 5 mm. Once this value was obtained the actual study proceeded. For each additive, as well as the control samples containing no additive, there were four 150 mm specimens made. The compacted specimens were allowed to cure on the laboratory bench for four hours prior to being subjected to the raveling test. The next section contains the test data obtained for all the trials using the various additives.

4.0 LABORATORY TEST DATA

The initial series of tests were run at ambient laboratory temperature, approximately 22°C. The material for all four specimens was produced at the same time and the manufacture of each briquette was spaced at 30-minute intervals to accommodate the raveling test parameters. This spacing also allowed for changing the rubber abrasion head when it needed to be replaced.

4.1 Cationic Emulsions

Table 2 shows the percent loss data obtained using the raveling test with the two cationic emulsions with the Portland Cement and Hydrated Lime.

Table 2. Raveling Test (% Loss) using Cationic Emulsions

Additive/Emulsion	CSS-1	CSS-1P
Control	4.5	7.1
0.5% Cement	1.9	6.7
1.0% Cement	2.1	2.0
0.5% Hydrated Lime	1.9	1.6
1.0% Hydrated Lime	2.1	1.3

The data shows that the control emulsions would fail to meet the specification requirements of 2.0 percent maximum loss as used by some American states. With the addition of the additives this specification requirement can be met. The additives tend to speed up the curing of the emulsion mix and allow the mix to develop improved cohesion and thus resist the abrasive forces of the rubber hose. Typical visual results of the raveling test that were obtained with these CIR mixes are shown in Figure 5.

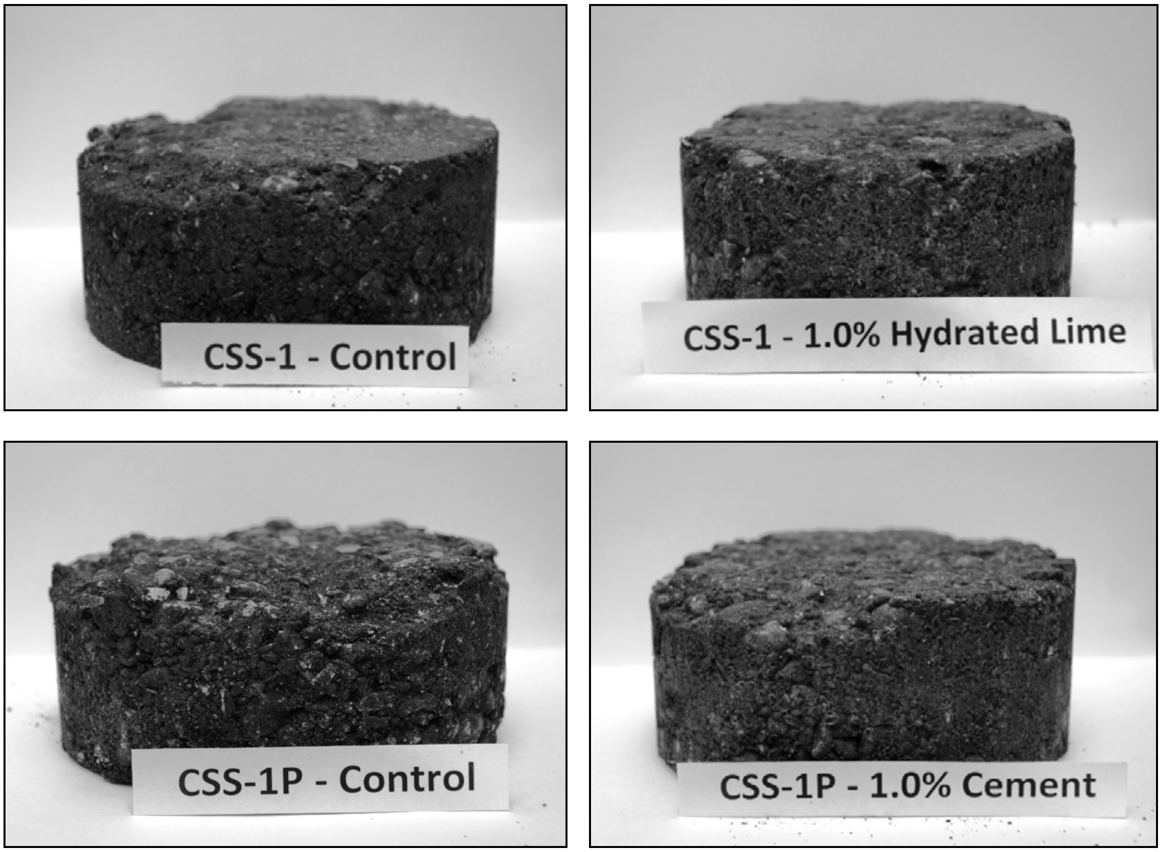

Figure 5. Raveling Test using Cationic Emulsions

4.2 High Float Emulsions

Table 3 shows the percent loss data obtained using the raveling test with the two high float emulsions with the Portland Cement and Hydrated Lime.

Table 3. Raveling Test (% Loss) using High Float Emulsions

Additive/Emulsion	HF150M	HF150M(P)
Control	3.1	2.0
0.5% Cement	1.8	3.4
1.0% Cement	3.0	2.0
0.5% Hydrated Lime	2.9	3.3
1.0% Hydrated Lime	1.7	1.7

The data indicates that the high float emulsions are relatively good in resisting the abrasive forces. The use of hydrated lime at a 1.0 percent dosage would meet the specification requirement. Figure 6 shows some visual photographs of the raveling test with these CIR mixes. These pictures are the average raveling based on the four specimens of each material tested.

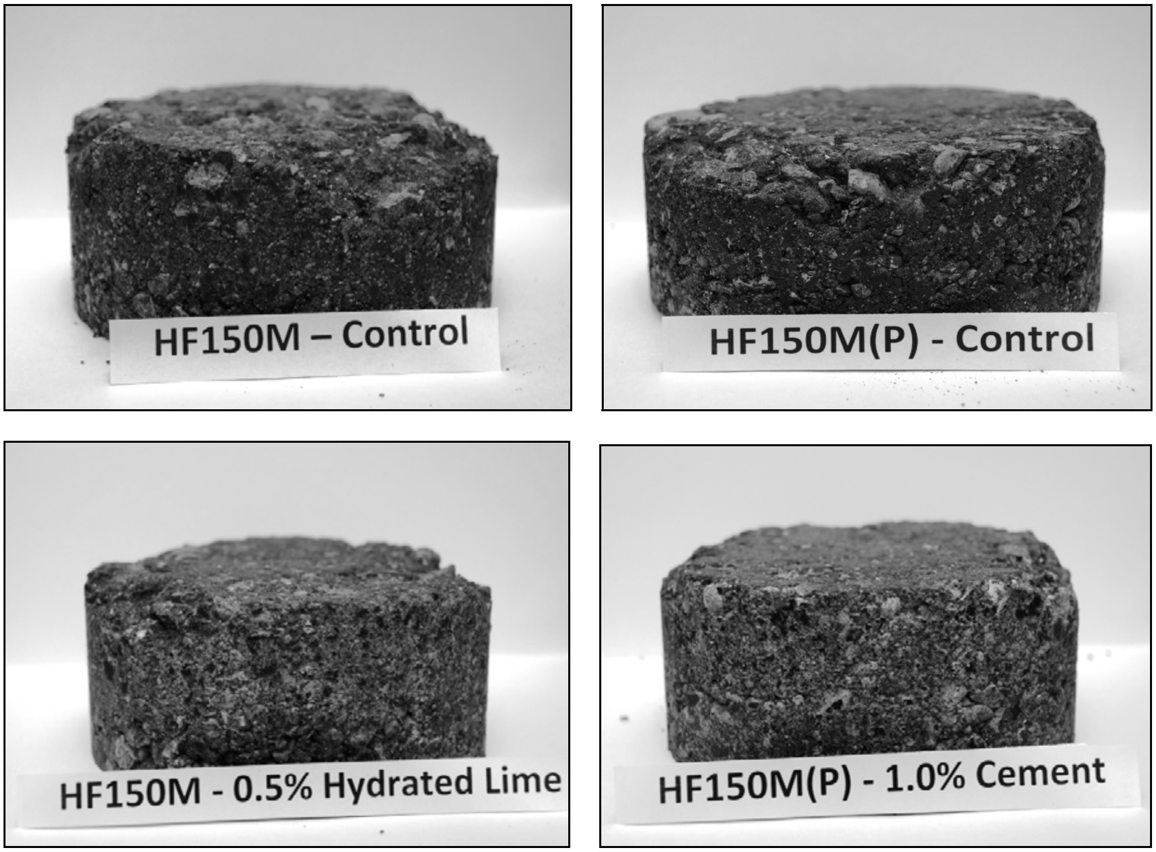

Figure 6. Raveling Test with High Float Emulsions

4.3 PG 58-28 Foamed Asphalt Cement Plus Additives

Table 4 shows the percent loss data obtained using the raveling test with PG 58-28 foamed asphalt cement with the five different additives.

Table 4. Raveling Test (% Loss) using PG 58-28 Expanded Asphalt

Additive	% Loss
Control	21.6
0.5% Cement	18.4
1.0% Cement	13.8
0.5% Hydrated Lime	19.6
1.0% Hydrated Lime	18.2
0.5% Evotherm Additive	12.6
0.5% Adhere 7700	10.0
1.0% UP5000	7.8

The test data obtained on the CIREAM mixtures using foamed asphalt cement show extensive raveling as compared to the asphalt emulsion mixes. Figure 7 shows some typical results of the expanded foam results versus the emulsion results.

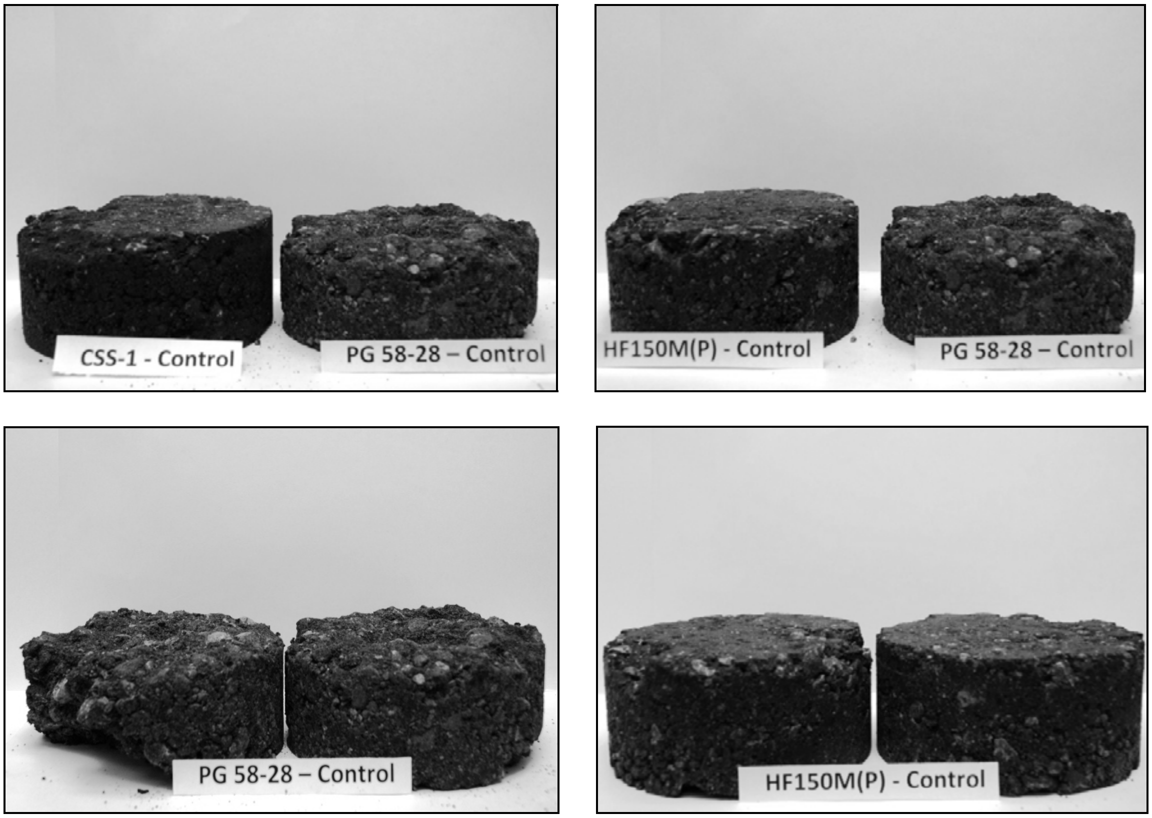

Figure 7. Emulsion versus Foam Raveling Results

Figure 8 shows pictures of the control mix and the additive mixtures using expanded asphalt. The pictures show the extensive raveling that has occurred.

The test results (average of four) gave a much wider range of values compared to the asphalt emulsions. There are improvements when the additives are used but the maximum specification values have still been exceeded. Table 5 gives some results of the spread of test data.

Table 5. Loss Data between Emulsion and Foam

Mixture	1	2	3	4	Average
CSS1 + 0.5% Cement	1.7	1.4	1.7	2.7	1.9
CSS-1P + 0.5% Lime	1.5	1.8	1.2	1.9	1.6
HF150M Control	2.5	1.8	5.1	2.0	3.1
HF150M(P) + 1.0% Cement	1.3	1.6	2.4	2.5	2.0
PG 58-28 Control	28.7	17.8	22.9	17.1	21.6
PG 58-28 + Adhere	12.0	8.5	9.4	9.9	10.0

Finally, the mixtures themselves have a much more open texture as compared to the asphalt emulsion samples as shown in Figure 9.

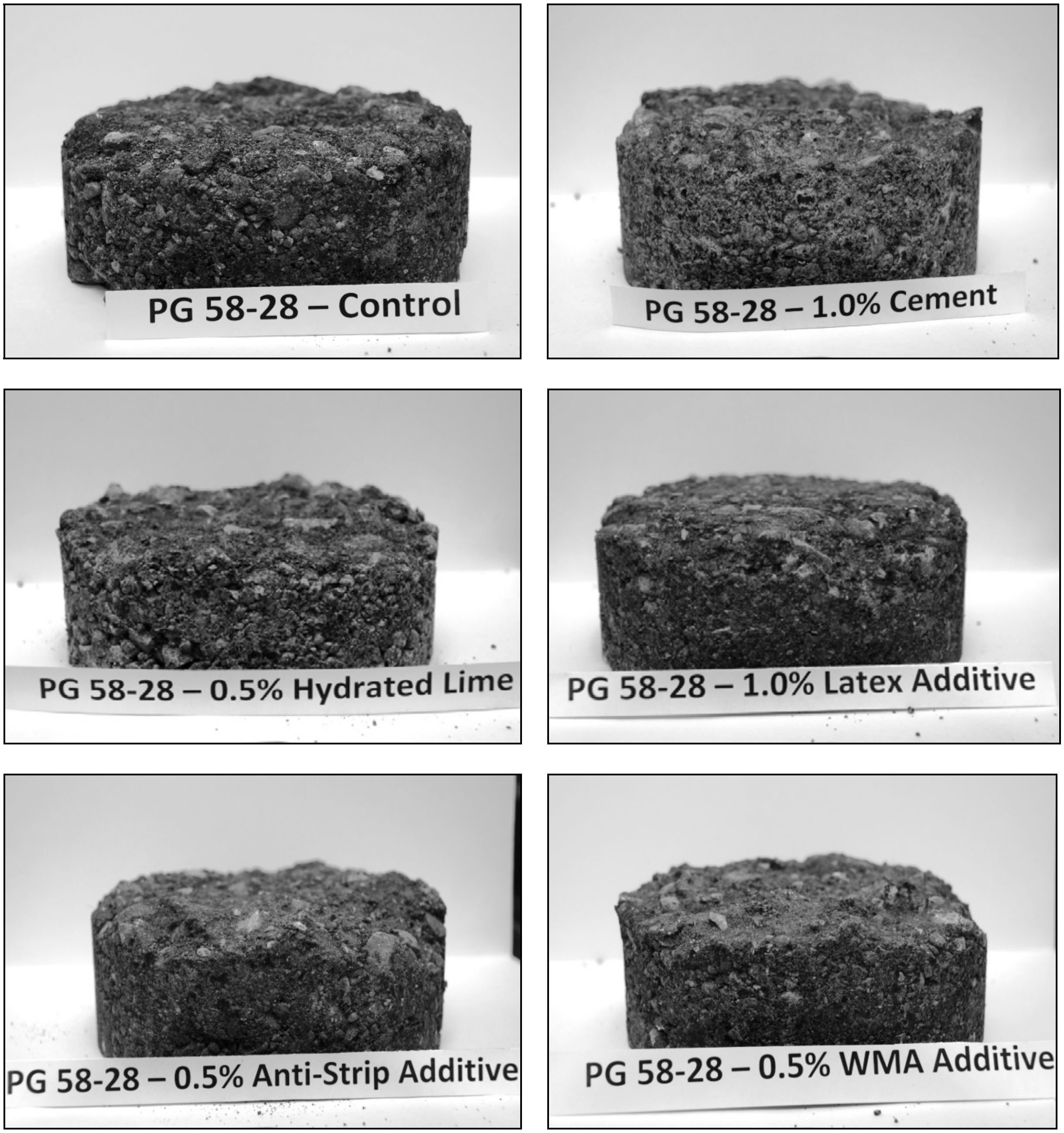

Figure 8. Raveling Test using PG 58-28 Asphalt and Additives

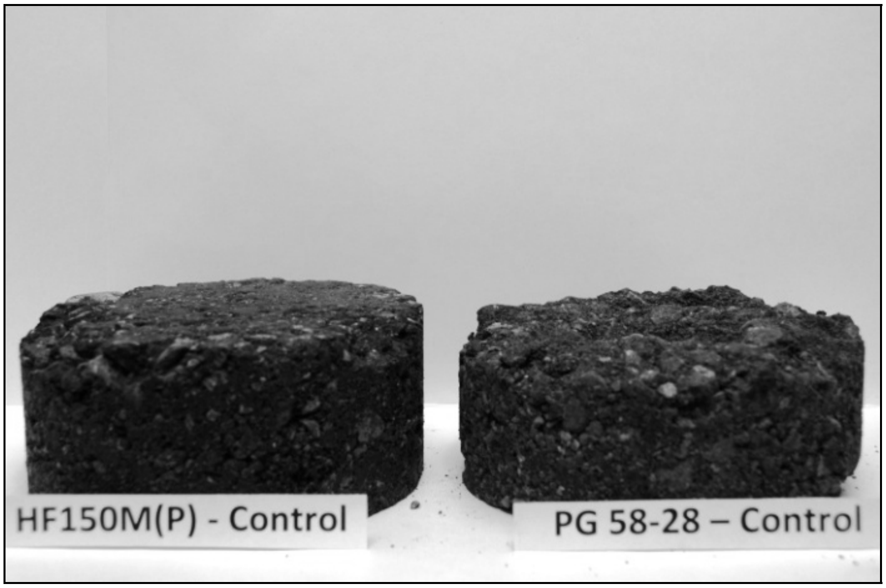

Figure 9. Texture Difference between Emulsion and Foam Mixes

5.0 CONCLUSIONS

This laboratory study is still ongoing with the evaluation of the both the emulsion and foamed mixes. Future work for this study will include the effects of lower temperatures on the compaction and raveling values, as well as the effects moisture may have on the raveling values. Based on the limited data obtained so far the following conclusions can be made.

- The mixtures manufactured using asphalt emulsions gave much lower raveling values and had a much tighter texture than the mixtures made with foamed asphalt.

- The variability of the test data was more pronounced with the foam mixes than with the asphalt emulsion mixes. This is most likely due to the tighter texture exhibited by the emulsion mixes, achieved due to better coating of the RAP as compared to the foam.

- The addition of Portland Cement or Hydrated Lime to the non polymer cationic emulsion mixtures gave improved raveling loss numbers as compared to no additive at all. The addition of more than 0.5 percent cement or lime does not appear to give any additional benefit to the CSS-1 emulsion. With the CSS-1P emulsion, the addition of cement or lime gave improved properties even up to 1.0 percent dosage.

- The hydrated lime worked very well with both the polymer and non-polymer anionic emulsion mixes up to the 1.0 percent dosage rate. The cement appears to provide benefits to the polymer high float emulsion but has an adverse effect on the non-polymer above 0.5 percent addition rate.

- With the foamed mixtures, all five additives aid in the reduction of raveling loss. The use of the non-traditional additives (WMA additive, Anti-stripping agent and latex) gave more reductions to the raveling loss than the cement or lime.

- The use of Portland Cement and Hydrated Lime chemically aid in the curing of the mixture. The quicker curing allows the mix to develop internal cohesion faster and thus give the recycled mix greater protection against raveling.

6.0 RECOMMENDATIONS

Based on the laboratory data collected in this study, the following recommendations are made:

1. The use of Portland Cement and Hydrated Lime in all types of cold in-place recycled mixes in Ontario with maximum limits of 1.0 percent by mass of mixture.

2. In CIREAM type mixes, the use of other additives besides cement and lime should be investigated.

The data reported in this paper is only the first phase of a three phase study investigating this issue of severe raveling and loss of texture observed in the last few years in CIREAM projects. The next two phases to be studied are: the effects of low temperature on both the compaction and raveling loss and the effects of moisture (rain which falls shortly after construction) on the texture and raveling loss.

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