Initial Evaluation of Foamed Asphalt Stabilization Using Modified Asphalt Cement

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Paper prepared for presentation

at the Soils and Materials: Warm Asphalt as a Sustainable Strategy for Pavements Session

of the 2008 Annual Conference of the
Transportation Association of Canada
Toronto, Ontario

ABSTRACT

With six experienced foamed asphalt stabilization contractors operation in Eastern Ontario, this method of pavement rehabilitation is now commonly used in this part of the province. The quality of foamed asphalt stabilized pavement depends on such factors as the uniformity of compaction achieved in the field, gradation of stabilized material and in particular the content of fines and mixture uniformity. It is typically required that the dry tensile strength should not be less than 300 kPa and for durability purposes, the Tensile Strength Ratio (TSR) should be not less than 50 percent.

Lafarge North America in cooperation with Roto-Mill Services Ltd. and Golder Associates has completed a pilot foamed asphalt stabilization project in Ontario using modified asphalt cement. Besides regular quality control/quality assurance testing, additional evaluation of the foamed asphalt stabilization, it included process monitoring, additional compaction testing using nuclear densometer (direct transmission method), sampling of materials and Falling Weight Deflectometer (FWD) testing.

The initial results of the evaluation are very encouraging. The compaction on both sections (asphalt and granular pavements) with modified asphalt cement was higher and more uniform than on the section with conventional material. The laboratory testing indicated that the tensile strength and the TSR of the modified material is higher that that of the conventional material. The structural capacity of the foamed asphalt layer with modified asphalt cement was significantly better than that of the layer with the conventional asphalt cement.

1.0 INTRODUCTION

As the overall condition of road pavements continues to deteriorate, the standard of road network continues to decline. The situation is getting worse as the volume of traffic continues to grow. This requires increasing effort to maintain and rehabilitate the existing pavements. Since most of road agencies face budget constrains, the focus is on achieving more with the same expenditure.

Recycling is one of the most effective methods to achieve these goals. Recycling also reduces the impact of pavement construction on environment by reusing depleting natural resources, reducing energy consumption and reducing green house emission [1 and 2]. The recycling methods used in Canada include hot in-place recycling, cold in-place recycling (CIR), full depth reclamation (FDR) with foamed (expanded) asphalt and emulsion and cold in-place recycling using expanded asphalt mix (CIREAM) [3].

With six experienced foamed asphalt stabilization contractors operation in Eastern Ontario, this method of pavement rehabilitation is now commonly used in this part of the province. The quality of foamed asphalt stabilized pavement depends on such factors as the uniformity of compaction achieved in the field, gradation of stabilized material and in particular the content of fines and mixture uniformity. Typical specifications, such as Ontario Provincial Standard Specification OPSS 331, require that a minimum of 97 percent of target density should be achieved. For durability purposes, the Tensile Strength Ratio (TSR) should be not less than 50 percent.

Lafarge North America in cooperation with Roto-Mill Services Ltd. and Golder Associates has completed a pilot foamed asphalt stabilization project on County Road 11 in Dufferin County in Ontario using modified asphalt cement. The additive to asphalt cement is a non-aqueous liquid based product and its formulation and properties are proprietary. The project included foamed asphalt stabilization of recycled asphalt pavement (about 35 percent RAP and 65 percent granular material) as well as 100 percent granular material with using conventional and modified asphalt cement. In addition, 1 percent of hydrated lime was also added on a selected short test section. Besides regular quality control/quality assurance testing, additional evaluation of the foamed asphalt stabilization was carried out. It included process monitoring, additional compaction testing using nuclear densometer (direct transmission method), sampling of materials and Falling Weight Deflectometer (FWD) testing.

2.0 EXISTING PAVEMENT AND REHABILITATION DESIGN

The existing pavement on County Road 11 consisted of one lift of hot-mix asphalt, about 50 mm thick, placed over about 250 mm thick granular base/subbase. The section to be foamed asphalt stabilized was about 1.2 km long. No pre-engineering was carried out and an off the shelf pavement rehabilitation design was selected by the County for this road. The rehabilitation design included foamed asphalt stabilization of the existing pavement to a depth of 150 mm and placement of a 50 mm of hot-mix asphalt surface course (HL 3 mix).

The pavement visual condition was carried out by Golder Associates Ltd. in accordance with the Ontario Ministry of Transportation (MTO) *"Manual for Condition Rating of Flexible Pavements"* SP-024. The inspection consisted of a visual pavement condition evaluation, including identification of type, severity and density of pavement surface distresses, noting significant surface features. Numerical values for Pavement Condition Rating (PCR) and Ride Comfort Rating (RCR) were also assigned to each section. The condition of the existing pavement was inconsistent. The west part of the road, about 0.8 km long, was seriously deteriorated and exhibited severe alligator, longitudinal and transverse cracking (Photograph 1). Two areas exhibiting the most severe alligator cracking, in total about 400 m, were repaired by the County before stabilization; the existing asphalt was removed together with the existing granular material and replaced with new granular material (Photograph 2). The east part of the road, about 0.4 km long, was relatively intact exhibiting only low to medium severity longitudinal and transverse cracking with only localized low severity cracking (Photograph 3). A Pavement Condition Rating (PCR) value of 44 and Riding Comfort Rating (RCR) of 4.6 were assigned to the existing pavement.

Photograph 1 High severity alligator cracking area on west part of the existing pavement on County Road 11.

Photograph 2 The pavement was repaired with new granular material before foamed asphalt stabilization in areas exhibiting the most severe alligator cracking.

Photograph 3 The pavement on the east part of County Road 11 was relatively intact with only low severity cracking.

3.0 MIX DESIGN

The mix design was carried out by AME Materials Engineering. The proportion of materials used in the mix design was 35 percent of RAP and 65 percent of granular material. The mix design was carried out in accordance with the Ontario Provincial Standard Specification, OPSS 331 [4]. The gradation of the mix design is given in Table 1. The mix design properties are given in Table 2. Conventional PG 58-28 asphalt cement was used in the design. The determined optimum water content was 2.75 percent. The half-life was 9 seconds and the expansion ratio was 9.

Table 1 Mix Design Gradation

Key Sieve Size	Percent Passing (%)
37.5 mm	100.0
4.75 mm	63.0
600 µm	27.1
75 µm	9.3

Table 2 Mix Design Properties

Properties	Design Value	OPSS 331 Requirements
Bulk Relative Density	2217	NA
Dry Tensile Strength	442 kPa	Minimum 300 kPa
Wet Tensile Strength	294 kPa	Minimum 150 kPa
Tensile Strength Ratio	67 %	Minimum 50 %
Recommended Expanded Asphalt Cement Content	3.0 %	Minimum 2.5 %

Additional testing at the mix design stage indicated that the Tensile Strength Ratio of the mix with 2.8 percent of foamed asphalt cement increased from 74 percent for the conventional PG 58-28 to 83 percent for a modified PG 58-28 (with additive).

4.0 CONSTRUCTION AND QUALITY CONTROL

The foamed asphalt stabilization was carried out by Roto-Mill Services Ltd. in November 2007. The existing pavement was stabilized to a depth of 150 mm. The amount of foamed asphalt added was adjusted to the type of stabilized material; 3.0 percent on foamed asphalt was added to the pulverized material on sections containing RAP and 3.75 percent on the two sections containing granular material only. There was not any additional mix design completed for the granular pavement sections. There were two types of asphalt cement used on this project: conventional PG 58-28; and modified PG 58-28 (with 0.6 percent additive). On a short section, 1.0 percent of hydrated lime was also added to the mixed material. There were five types of stabilized materials as shown in Table 3.

Table 3 Types of Foamed Asphalt Material

No.	Asphalt Cement	Other Additives	Existing Pavement	Material Code
1	with additive	-	asphalt	$A_{additive}$
2	with additive	-	granular	$G_{additive}$
3	without additive	-	asphalt	$A_{without\ additive}$
4	without additive	-	granular	$G_{without\ additive}$
5	without additive	hydrated lime	asphalt	$AL_{without\ additive}$

Photograph 4 shows the recycling train working on County Road 11. The monitoring of the construction process included identifying the locations of each type of stabilization, material sampling, compaction testing using a nuclear gauge, obtaining information about asphalt cement temperature and taking photographs of the stabilization process. As shown in Figure 1, the foaming with the additive was carried out generally in the west part of the road section and without additive in the east part of the road section. It is important to note that condition of the existing pavement was significantly worse in the west part of the road due to the presence of extensive alligator cracking (Photograph 5).

Photograph 4 The recycling train working on County Road 11.

Photograph 5 Areas exhibiting severe alligator cracking being foamed asphalt stabilized.

Compaction testing was carried out the existing granular pavement and the foamed asphalt mat using a direct transmission method. A summary of foamed asphalt mat compaction testing is presented in Table 4. Much better compaction was achieved on the sections where modified asphalt cement was used, although the compaction effort was kept consistent on the entire road section.

Material Code	Average Field Compaction* (%)		
	EBL	WBL	Mean
$A_{additive}$	97.4	100.5	99.0
$A_{without\ additive}$	94.7	95.3	95.0
$G_{additive}$	100.9	100.6	100.8
$G_{without\ additive}$	99.6	-	99.6
$AL_{without\ additive}$	92.5	-	92.5

* Percent of target density.

As part of the quality control, the gradation and the tensile strength of the foamed asphalt materials were determined. Table 5 shows a summary of the test results.

Table 5 Summary of Gradation and Tensile Strength Testing Results

Average Gradation	
Sieve Size	Percent Passing
37.5 mm	100.0
4.75 mm	56.1
600 µm	25.9
75 µm	7.0

Average Tensile Strength		
Dry (kPa)	Wet (kPa)	TSR (%)
569	476	83.6

5.0 ADDITIONAL LABORATORY EVALUATION

Twenty test slabs were cut from the stabilized mat and delivered to the Golder laboratory for testing. The locations of the slabs are shown in Figure 1. In the laboratory, the slabs were first logged and photographs were taken. Then 150 mm cores were extracted from the slabs for the density and tensile strength testing. Photographs 6, 7 and 8 compare the cores obtained from sections with conventional and modified foamed asphalt stabilization. Generally, the appearance of the cores from the modified sections was significantly better, more sound with less damage caused by the coring operation.

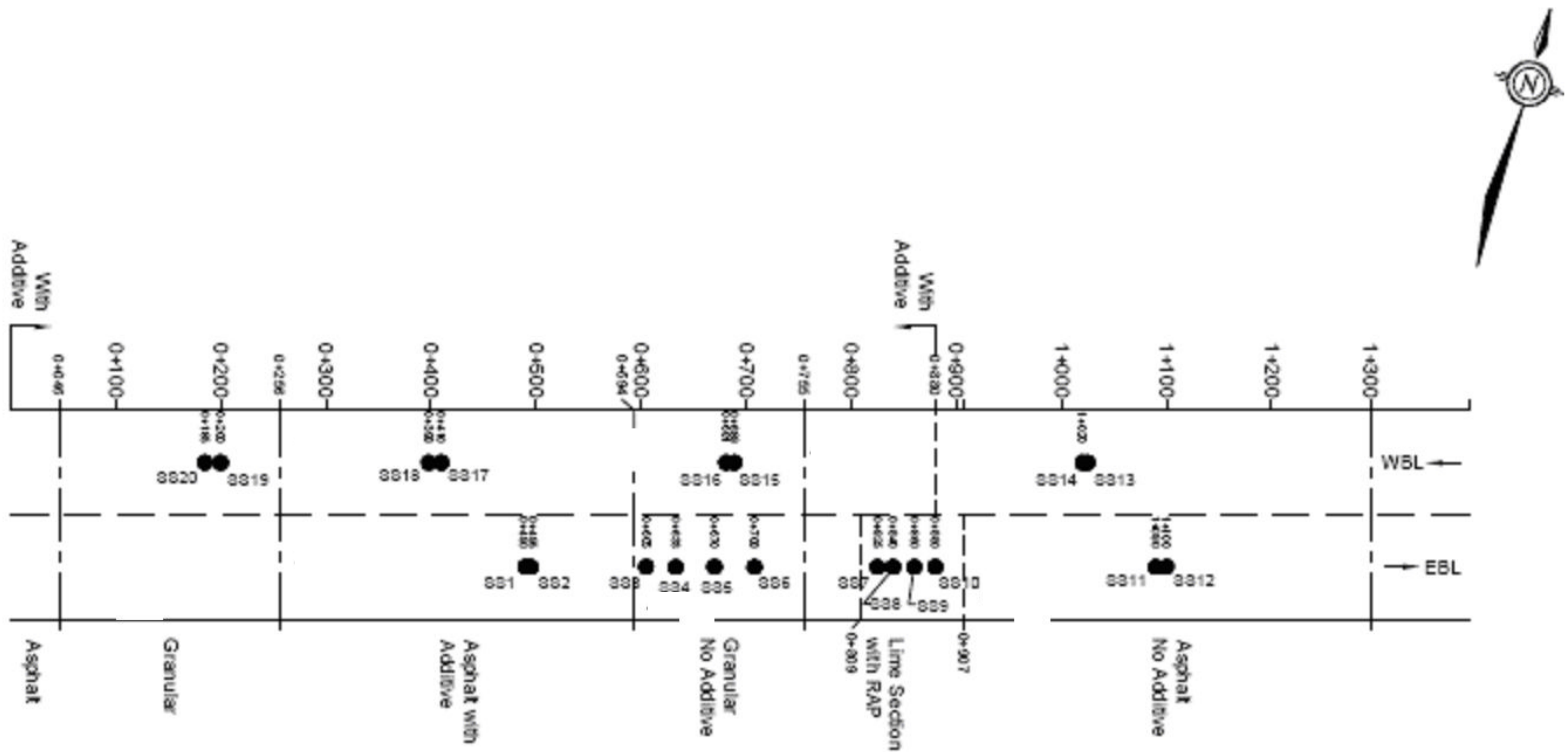
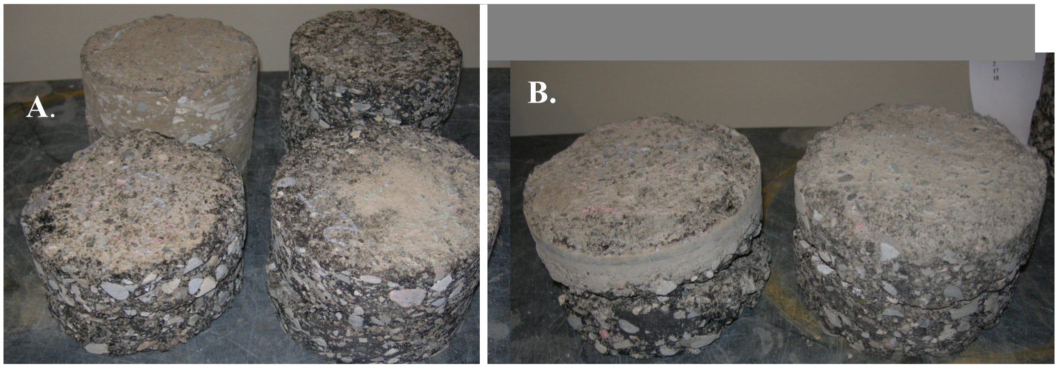
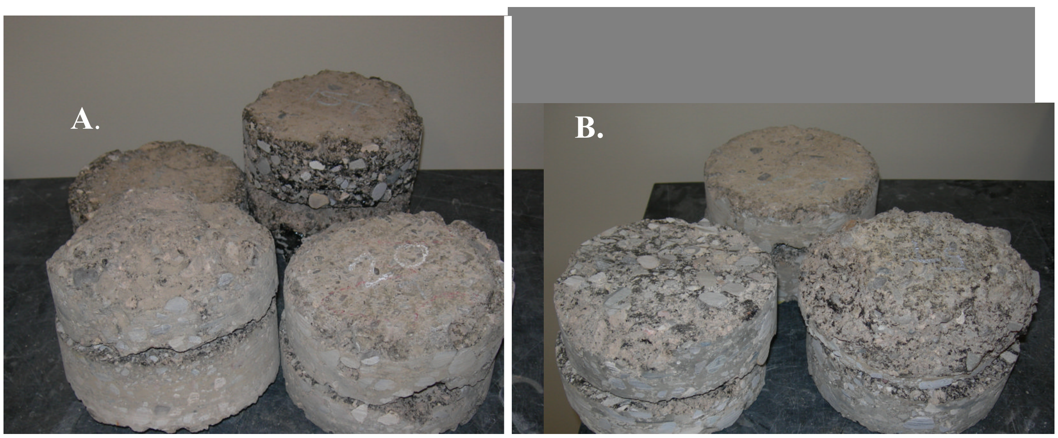


Figure 1 Sample locations on County Road 11.



Photograph 6   Cores of asphalt pavement stabilized with modified foamed asphalt (A) and conventional foamed asphalt (B).



Photograph 7   Cores of granular pavement stabilized with modified foamed asphalt (A) and conventional foamed asphalt (B).

Photograph 8   Cores of asphalt pavement stabilized with conventional foamed asphalt and lime.

Each core was then split into halves and the core bottom and top part densities and compactions were determined. Table 5 shows the summary of the core compaction testing. The average compaction of the cores obtained from asphalt pavement stabilized with modified foamed asphalt is higher by 1.5 percent than those from the conventional foamed asphalt section. The compaction of both types of cores obtained from granular pavement is very similar. Interestingly, the difference in compaction between the top and bottom parts of the cores was small, 0 to 2 percent.

Table 5 Summary of Slab Compaction Results

Material Type	Compaction (%)	Core Bottom BRD/ Core Top BRD
$A_{additive}$	96.7%	99%
$A_{without\ additive}$	95.2%	98%
$G_{additive}$	99.0%	100%
$G_{without\ additive}$	99.1%	101%
$AL_{without\ additive}$	96.2%	98%

Table 6 shows a summary of the tensile strength testing. Only the samples with the modified foamed asphalt met the OPSS 331 requirements for the wet and dry tensile strength (minimum 300 kPa for the dry strength and minimum 150 kPa for the wet strength) and the TSR (minimum 50 percent).

Table 6 Summary of Slab TSR Results

Material Type	Average Tensile Strength* (kPa)		Average TSR (%)
	Dry	Wet	
$A_{additive}$	323	215	67%
$A_{without\ additive}$	224	103	46%
$G_{additive}$	334	153	46%
$G_{without\ additive}$	365	163	45%
$AL_{without\ additive}$	263	180	69%

* Some core damage was observed during the coring operation.

It also appears that the increase of the foamed asphalt content from 3.0 percent for asphalt pavement to 3.75 percent for granular pavement was not sufficient.

6.0 PAVEMENT STRUCTURAL CONDITION TESTING

The new pavement on County Road 11 is in very good condition; however, some segregation of the new surface course was observed at number of locations (Photograph 11). Although the segregation of the surface course is not related to the quality of foamed asphalt layer, it will likely impact the long term performance of the pavement.

Photograph 11 Pavement condition in April 2008.

As part of this research, the Falling Weight Deflectometer (FWD) load/deflection testing was carried out in November 2008. The testing was completed at 20 m intervals in both lanes staggered by 10 m. The applied loading pulses were about 30 kN, 40 kN and 50 kN. The deflection was recorded by 9 geophones. The FWD analysis included the determination of deflection and pavement surface modulus, both normalized to a standard load of 40 kN and a standard temperature of 21°C. In addition, the resilient modulus of the foamed asphalt layer was also determined. As the average thickness of the foamed asphalt layer was about 125 mm, not 150 mm, as initially anticipated, the foamed asphalt layer modulus was calculated assuming the thickness of 125 mm. A summary of pavement deflections and foamed asphalt layer modulus is given in Table 7. The modulus is also shown in Figures 2 to 3.

Table 7 Summary of Pavement FWD Deflections and Foamed Asphalt Layer Modulus Results

Parameter	Material Code	Mean Value	Improvement (with additive vs. without additive)	
			Value	Percent
Deflection	$A_{additive}$	0.35 mm	0	0
	$A_{without\ additive}$	0.35 mm	-	-
	$G_{additive}$	0.39 mm	0.03 mm	8 %
	$G_{without\ additive}$	0.42 mm	-	-
	$AL_{without\ additive}$	0.36 mm	-	-
Foamed Asphalt Layer Modulus	$A_{additive}$	1,325 MPa	199 MPa	18 %
	$A_{without\ additive}$	1,126 MPa	-	-
	$G_{additive}$	1,164 MPa	232 MPa	25 %
	$G_{without\ additive}$	932 MPa	-	-
	$AL_{without\ additive}$	1,062 MPa	-	-

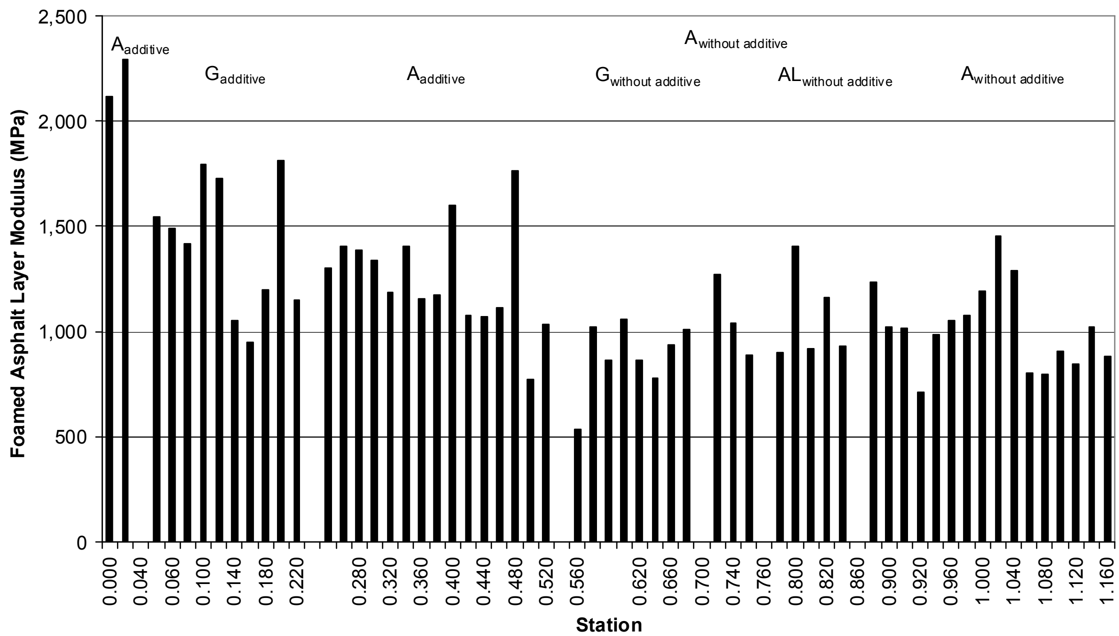


Figure 2 Foamed asphalt layer modulus, EBL.

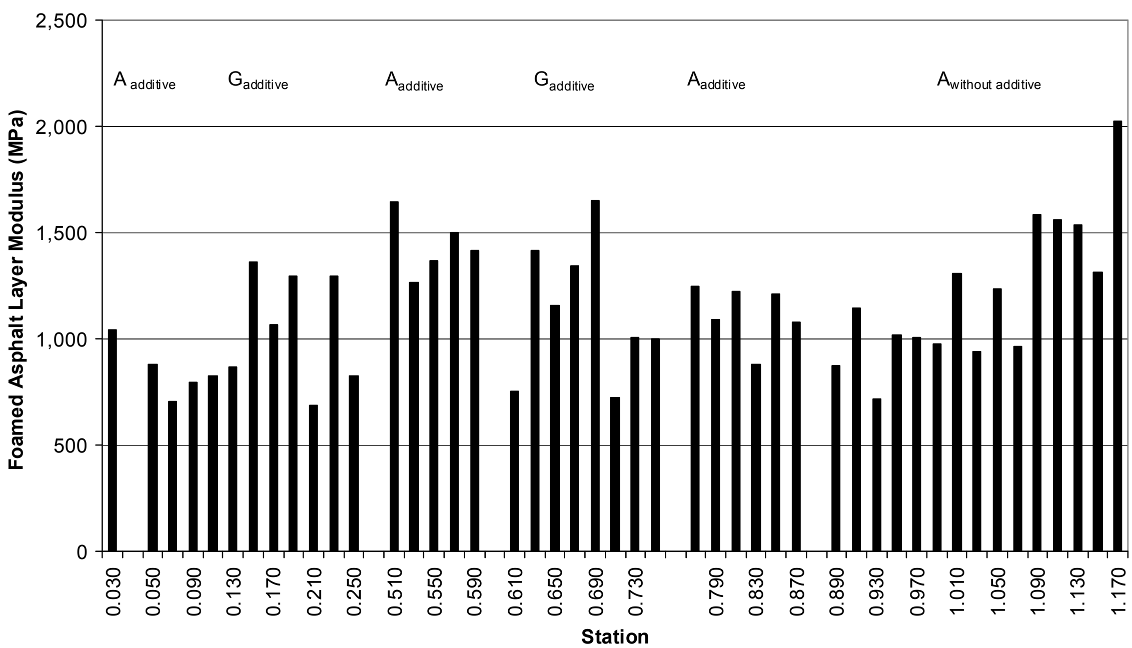


Figure 3 Foamed asphalt layer modulus, WBL.

The average deflections on modified and conventional sections of stabilized asphalt pavement are the same; however, it should be noted that the condition of the original asphalt pavement where the conventional foamed asphalt was used was much better than on the modified section. The foamed asphalt layer modulus on the modified asphalt pavement section is significantly higher that on the conventional asphalt pavement section (1,325 MPa and 1,126 MPa, respectively).

7.0 FINDINGS

There were obvious benefits of using the modified asphalt cement in the foamed asphalt stabilization observed during construction process and laboratory evaluation. They included:

1. Achieving higher and more uniform compaction in the filed while applying the same compaction effort;
2. The tensile strength and TSR values were higher; this indicates that the material should be less sensitive to moisture damage;
3. The structural capacity in terms of foamed asphalt layer modulus was higher and more uniform;
4. The appearance of the cores was better, they looked more sound and exhibited less damage due to coring operation; and
5. The TSR value of the material with modified asphalt cement is somewhat similar to that of the material with conventional asphalt cement and 1 percent of hydrated lime; however, the application of the modified asphalt cement is much easier and of significantly lower cost.

As anticipated and observed on other foamed asphalt stabilization projects, the tensile strength and TSR values obtained on samples prepared in the laboratory using the Marshall moulds are significantly higher than those obtained on slabs or cores obtained in the field.

The extent of this research was somewhat limited. It is recommended that the research on the performance of foamed asphalt stabilization using modified asphalt cement be continued. In particular, the condition of the sections of the original pavement where the modified and conventional asphalt cement were used should be similar and also more samples should be prepared in the laboratory using the asphalt foamer. Then, life-cycle cost analysis could be carried out to evaluate the cost effectiveness of this material.

REFERENCES

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