Geosynthetics - 7th ICG - Delmas, Gourc & Girard (eds) © 2002 Swets & Zeitlinger, Lisse ISBN 90 5809 523 1

The effect of glass-sheet reinforcement on crack resistance of asphalt concrete

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ABSTRACT: The objective of this paper is to evaluate crack resistance asphalt pavement due to geosynthetics (glass-sheet) reinforcement on interface between the surface and base layer. A glass-sheet reinforced asphaltic composite specimen was made with two different asphalt and three different pavement thickness for the laboratory evaluation. Three point static bending beam test at -10º C and three point fatigue bending beam test at 5º C were conducted for the evaluation. Test result shown that an addition of glass-sheet reinforcement in asphalt pavement system may affects a significant influence on crack resistance of the pavement: with polymer reinforced asphalt, the fatigue life of glass-sheet reinforced composite specimen increased up to thirteen times.

1 INTRODUCTION

Recent development in Korean industry caused a permanent deformation and a reflection cracking on asphalt pavement in a large scale, and many asphalt-related researches have focused to resolve those pavement deteriorations. As a result, a series of engineered asphalt technologies, such as polymer modified asphalt, stone mastic asphalt pavement, and SUPERPAVE level I mix design, etc., have introduced in Korea, and some of them are implemented successfully. Yet, those pavement deteriorations are still a major concern for highway agencies on a place like urban intersections and heavy weight traffic sections. With this background, Ministry of Construction and Transportation has launched a research program to investigate a pavement technology to increase durability of asphalt pavements using geosynthetics-reinforcement in asphalt pavement layers.

Use of geosynthetics within an asphalt pavement has been a series of research topics over years. An addition of geosynthetics interlayers between HMAC layers in asphalt pavement is believed to increase a performance of crack resistance by many researchers(Koerner, 1992; Dondi, 1998; Austin & Gilchrist, 1996; Huhnholz, 1996; Bayex, 1998). In addition, because of its water-tightening characteristics, it could behave as an water proofing layer in asphalt pavement(Marienfeld & Smiley, 1994). Komatsu et al.(1998) and Brown et al.(1985 a, b) reported that geosynthetics interlayers in HMAC could increase a resistance of rutting as well as cracking on asphalt pavements.

Implementation of geosynthetics reinforcement on asphalt pavement, however, it was not very successful because of technical difficulties on construction stage as well as uncertainties on reinforcement effect between asphaltic layers. Recently, a series of effort has been made to improve a performance of geosynthetics in terms of easier application on construction as well as for better reinforcement in asphaltic layers; however, those performance has not thoroughly evaluated..

2 OBJECTIVE

The objective of this paper is to evaluate crack resistance asphalt pavement due to geosynthetics (glass-sheet) reinforcement on interface between the surface and base layer. The effect of geosynthetics interlayer on performance of crack resistance is assessed through laboratory experiment. A glass-sheet geosynthetics was selected for the evaluation over various type of asphalt and surface layer thickness. In order to simulate a field condition, the test specimen (a composite beam of asphalt concrete and geosynthetics) were compacted in test pit with rolling wheel compactor and sawed/cored to test sample size. The following controlled factor were included in the experiment;

- 2 geosynthetics reinforcements (glass-sheet, and control)
- 2 asphalt binders (straight asphalt and SBS modified asphalt)
- 3 combinations of layer thicknesses (variations in layer thickness for surface and asphaltic base courses)

3 point fatigue bending beam test at 5º C and 3 point static bending beam test at -10º C were conducted on geosynthetics-reinforced asphalt concrete composite beam, and test results were analyzed to evaluate the resistance of cracking.

3 MATERIALS AND TESTING PROCEDURES

3.1 *Materials*

A crushed granite with maximum size of 13mm for surface mixture and 35mm for base mixture was used in this study, and its gradation chart is on table 1. A straight asphalt (PG 64-22) and SBS modified asphalt (PG 76-22) were used for the study. Marshall mix design method was used for optimum asphalt content for the mixture.

Table 1. Asphalt Mixture Used in the Study.

	Top Agg. Size	Gradation	Asphalt Grade	Asphalt Content
Asphalt Surface -1	13mm	Dense Graded	PG 64-22 (Straight)	5.95%
Asphalt Surface -2	13mm	Dense Graded	PG 76-22 (SBS Modified)	5.73%
Asphalt Stabilized Base	37.5mm	Dense Graded	PG 64-22 (Straight)	3.95%

A glass-sheet were selected for the study. The glass-sheet is an array of glass fiber sheet with a thin bond layer (mix of asphalt and sand) for ease of construction. Figure 1 shows diagram of the glass-sheet used in the study and table 2 is a summary of its mechanical characteristics.

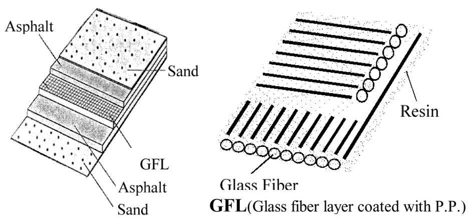

Figure 1. Diagram of the Glass-sheet Used in the Study

Table 2. Summary Table for Geosynthetics Used for the Study.

Reinforcement	Glass-fiber	
GFL	Thickness	0.25 mm
	Surface Weight	210 g/m^2
Asphalt	Softening Point	110º C
	Viscosity	6 Pa.S
Sheet	Thickness	2.0 mm
Thermal Characteristics	Coef. of Thermal Expansion	5×10^{-6}
Tensile Characteristics	Max. Tensile Strength	68 kN/m
	Max. Tensile Strain	2 %

3.2 *Test Specimen Preparation*

In order to simulate field condition, test specimen was produced on a 10meter x 10meter sample preparation pit. The sample preparation pit is consist of 30cm thick crushed stone subbase, 12cm thick 35mm top size HMAC base. On top of the HMAC base, a 80cm x 120cm size of 13mm top size HMAC slab was laid and compacted with a rolling wheel compactor to 96% of laboratory compacted density. Table 3 summarizes the materials and dimensions for the sample preparation pit. As shown on the table, the surface slab was compacted to either 5cm or 3cm thickness depending on the test scheme. After the compaction, the slab was either sliced or cored to test specimen size for experiment as shown on table 3.

Table 3. Summary Table for Sample Preparation Pit and Controlled Factor for the Study

	Thickness (cm)	Asphalt type	Aggregate			Mix design
			Top size (mm)	Gradation	Aggregate Source	Asphalt content (%)
Surface	5 (3)	PG 64-22 PG 76-22	13	Dense grade	Granite	
Interlayer	None Glass sheet					
Base	10 (7)	PG 64-22	35	Dense grade	Granite	
Subbase	20	None	50	-	Granite	Crushed stone subbase

Gray marked cells are the controlled factor for the study

3.3 *Test Procedures*

In order to understand the behavior of geosynthetics-reinforced asphalt concrete composite materials, a series of laboratory experiments, that includes Three point static bending beam test at -10º C and three point fatigue bending beam test at 5º C were conducted. Table 4 summarized the test procedures used in this study.

3.3.1 *3 point static bending beam test*

Figure 2 shows a diagram for 3 point static bending beam test used in the study. In order to observe the effect of reinforcement by the geosynthetics, a notch was made at the bottom center of the beam specimen right beneath to the reinforcement layer. A hydraulic loading frame was used to provide the loading condition selected. An applied load and deformation were monitored for the evaluation.

Table 4. Test Condition for the Study

	3 Point Fatigue Bending Beam Test	3 Point Static Bending Test
Applied Load (Kg)	10 - 250	Constant deformation rate of 0.5in/sec
Load Frequency	10 Hz	N/A
Test Temperature	5°C	-10°C
Sample size (W x D x H, mm)	300 x 75 x 150/130	350 x 50 x 60

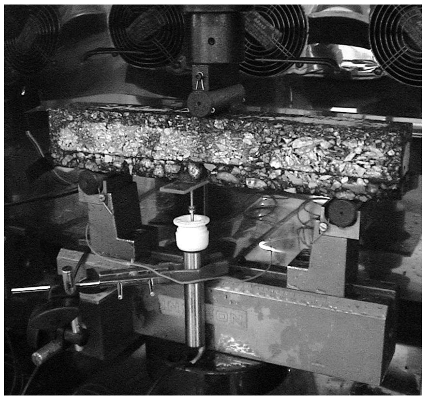

Figure 2. 3pt. Static Bending Beam Test

3.3.2 *3 point fatigue bending beam test*

Figure 3 shows a diagram for 3pt. fatigue bending beam test. Through preliminary test, the fatigue load was decided to 250kg with frequency of 10Hz at 5°C. A hydraulic loading frame was used to provide the loading condition selected. A crack propagation and load cycle were measured along with load and deformation. Since the notch ratio of test specimen for 5cm surface was different from that of 3cm surface, test result was assessed only within the same notch ratio group.

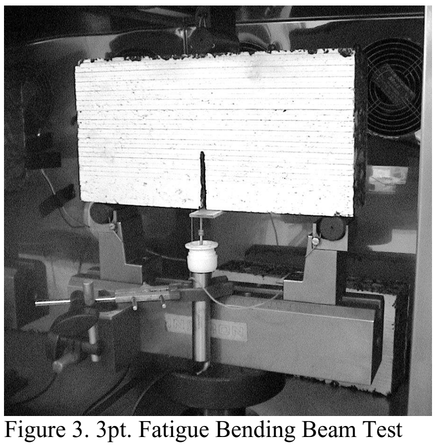

Figure 3. 3pt. Fatigue Bending Beam Test

4 TEST RESULTS

4.1 *3 point static bending beam test*

Comparisons of test results between reinforced and non-reinforced specimen indicated that introduction of glass-sheet reinforcement interlayer affected the flexural strength and toughness of the composite beam specimen. Table 5 summarizes the test results, and Figure 4 through 5 show the typical patterns of glass-sheet

Table 5. 3pt. Static Bending Beam Test Results

Reinforcement		Variable	Max. Load (kg)	Max. Deflection (mm)	Toughness (kgf*mm)	Duration to Fracture (sec)
PG 64-22	None	Rep. 1	202.7	0.428	41.5	0.44
		Rep. 2	139.6	0.482	22.4	0.39
		Rep. 3	203.3	0.492	50.6	0.54
		Avg. (%*)	181.9 (100%)	0.468 (100%)	38.2 (100%)	0.46 (100%)
	Glass -sheet	Rep. 1	313.3	3.905	805.5	3.77
		Rep. 2	349.5	4.195	952.5	4.89
		Rep. 3	315.1	3.277	789.8	3.95
		Avg. (%*)	326.0 (179%)	3.792 (811%)	849.2 (2225%)	4.20 (920%)
PG 76-22	None	Rep. 1	148.9	0.579	41.8	0.70
		Rep. 2	146.8	0.441	35.4	0.52
		Rep. 3	182.2	0.701	59.4	0.72
		Rep. 4	156.3	0.419	43.3	0.50
		Avg. (%*)	158.6 (87%)	0.535 (114%)	45.0 (118%)	0.61 (134%)
	Glass -sheet	Rep. 1	406.6	4.504	1274.1	5.17
		Rep. 2	360.9	4.145	997.6	4.12
		Rep. 3	-	-	-	-
		Rep. 4	-	-	-	-
		Avg. (%*)	383.7 (211%)	4.324 (925%)	1135.8 (2976%)	4.64 (1017%)

* Ratio to Controlled Specimen (Non-reinforced, PG 64-22)

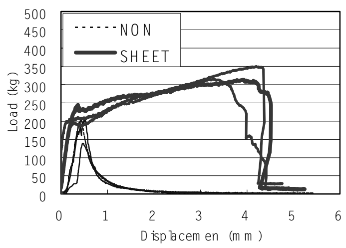

Figure 4. 3pt. Static Bending Beam Test (PG 64-22)

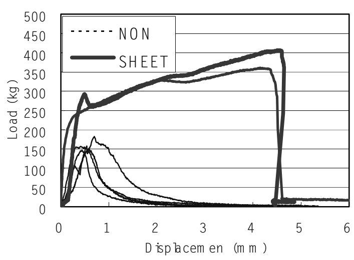

Figure 5. 3pt. Static Bending Beam Test (PG 76-22)

As shown in the figures, introduction of glass-sheet reinforcement in asphalt concrete composite beam affects the behavior of the composite beam significantly. While non-reinforced specimen shows a rapid decrease in load after the peak load, reinforced specimen typically shows two load peaks during the test. Also, it shows a significant increase in test duration to fracture. This significant difference in flexural behavior appears to be due to a reinforcing effect by glass-sheet interlayer: the reinforcing effect starts to emerging after the first peak load. The influence of asphalt type on flexural behavior was minimal. This results agree with previous research findings that SBS asphalt modifier does not help low temperature behavior of asphalt around -10°C (Kim et al.1999).

The test data shows a significant increase in maximum deflection and fracture energy (toughness) by glass-sheet reinforcement. As shown in Figure 6 and 7, glass-sheet reinforced asphalt concrete specimen shows 7 times increase in maximum deflection and 20 times increase in toughness compares to control specimen. The effect of SBS modifiers on these properties was not significant.

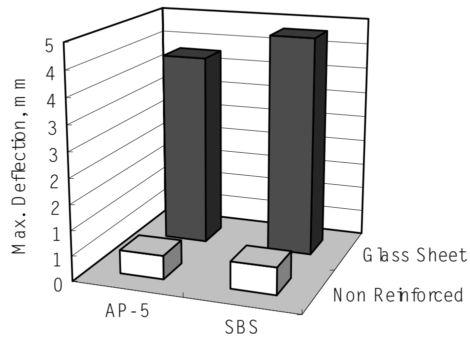

Figure 6. Changes in Max. Deflection on. 3pt. Static Bending Beam Test

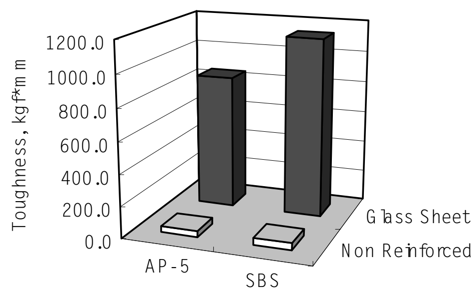

Figure 7. Changes in Toughness on . 3pt. Static Bending Beam Test

4.2 *3 point fatigue bending beam test at 5° C*

A 3 point fatigue bending beam test result can be summarized as follows.

Non-Reinforced Specimen

- As for the non–reinforced specimen, a longer fatigue life was observed on test specimen with thicker layer (surface and base layer).
- A reduction in surface layer thickness introduced more decrease in fatigue life than a reduction in base layer thickness with the same reduction ratio
- Use of SBS modified asphalt showed a increase in fatigue life of test specimen more than 3 times.

Glass-sheet Reinforced Specimen

- In specimen with thicker thickness in surface and base layers and with use of SBS modified asphalt showed longer fatigue life.
- A reduction in surface layer thickness induced a significant decrease in fatigue life.
- Comparing to a fatigue life of non-reinforced specimen, a fatigue life of glass-sheet reinforced specimen showed more than 8 times. With use of SBS modified asphalt, a fatigue life of glass-sheet reinforced specimen increased 13 times more than controlled specimen.

In all cases, glass-sheet reinforced interlayer remained good bonding during the 3 point fatigue bending beam test. While a test specimen with no reinforcement break up into two pieces at the end of test, glass-sheet reinforced specimen did not break into two pieces even after the fatigue crack developed to the top of the sample.

Table 6 summarizes the test results, and figure 8 through 9 show the fatigue life of test specimen for various asphalt and layer thickness. As shown in the figures, use of SBS modified asphalt and use of thicker layer (surface and base layer) induced a longer fatigue life on composite specimen. Among these two variables, influence of binder on fatigue life was more significant than variation in layer thickness. In average, use of SBS modified asphalt on non-reinforced composite beam resulted in more than 3 times in fatigue life than controlled specimen.

Table 6. Summary Table for 3 point Fatigue Bending Beam Test at 5º C

Properties	Test Variables	No Reinforcement			Glass-sheet Reinforcement		
		5-10*	5-7*	3-10*	5-10*	5-7*	3-10*
Load Cycle to Fracture	PG 64-22 (ratio)	30,073 (100%)	16,659 (100%)	5,494 (100%)	273,251+ (909%↑)	173,650 (1,042%)	18,857 (343%)
	PG 76-22 (ratio)	111,578 (371%)	105,699 (635%)	32,839 (598%)	400,000+ (1,330%↑)	400,000+ (2,401%↑)	21,703 (395%)
LVDT Amplitude at Fracture	PG 64-22	0.0428	0.0602	0.0587	0.4504	0.4558	0.0800
	PG 76-22	0.0440	0.0246	0.0505	0.2034	0.0718	0.0619
LVDT Deflection at Fracture	PG 64-22	4.6816	3.7658	4.9210	6.7180	5.4318	6.9712
	PG 76-22	7.5924	5.9694	9.4773	5.8865	3.6644	4.3860

Thickness of Specimen in centimeters (Surface– Base)
+ Test Suspended without Fracture

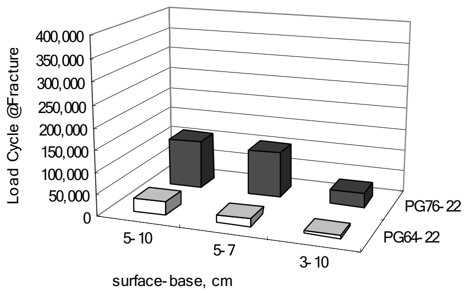

Figure 8. 3pt. Fatigue Bending Beam Test Result (Non-reinforced)

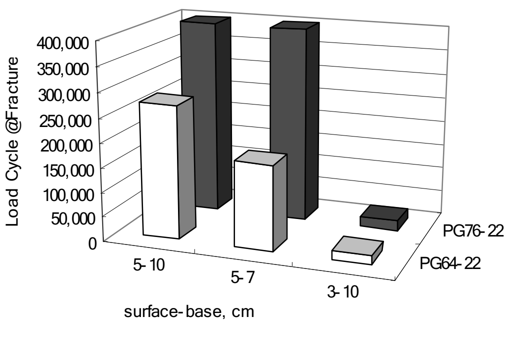

Figure 9. 3pt. Fatigue Bending Beam Test Result (Glass-sheet reinforced)

As shown in figure 9, introduction on glass-sheet reinforcement resulted in a significant increase in fatigue life, while the effect of other variables, i.e., binders and layer thickness, still observed as the non-reinforced case.

Thus, comparing to a fatigue life of non-reinforced specimen, a fatigue life of glass-sheet reinforced specimen showed more than 8 times. With use of SBS modified asphalt, a fatigue life of glass-sheet reinforced specimen increased 13 times more than controlled specimen.

5 CONCLUSIONS

In this study to evaluate crack resistance asphalt pavement due to geosynthetics (glass-sheet) reinforcement on interface between the surface and base layer, the conclusion may be summarized as follows.

- Introduction of glass-sheet reinforcement in asphalt composite specimen induce a significant increase in maximum deflection and fracture energy at -10º C.
- Introduction of glass-sheet interlayer in asphalt pavement system could induce a significant increase in fatigue life at 5º C. With use of SBS modified asphalt, a fatigue life of glass-sheet reinforced specimen increased 13 times more than controlled specimen.
- During the sample preparation and test, glass-sheet interlayer remained good bonding between surface and base layer.
- Thus, glass-sheet interlayer appears be a feasible alternatives for improving a crack resistance in asphalt pavement.

6 REFERENCE

Austin, R.A. and Gilchrist, A.J.T. 1996, "Enhanced Performance of Asphalt Pavement Using Geocomposites," Geotextiles and Geomembranes, Vol. 14, pp. 175~186.

Barksdale, R.D. 1991, "Fabrics in Asphalt Overlays and Pavement Maintenance," Report NCHRP 171, TRB, Washington, D.C.

Bayex 1998, "Pavement Reinforcement Grids Help Resist Cracking," Geotechnical Fabrics Report, January/February, p. 46.

Brown, S.F., Brunton, J.M., Hughes, D.A.B. and Broderick, B.V. 1985 a, "Polymer Grid Reinforcement of Asphalt," Annual Meeting of the Association of Asphalt Paving Technologists, Texas, pp. 18~44.

Brown, S.F., Hughes, D.A.B. and Broderick, B.V. 1985 b, "The Use of Polymer Grids for Improved Asphalt Performance," Eurobitume Conference, The Hague, Netherlands.

Dondi, G. 1998, "Effectiveness of Synthetic Interlayers in Bituminous Pavements," Proc. of 6th International Conference on Geosynthetics, pp. 977~984.

Huhnholz, M. 1996, "Asphalt Reinforcement in Practice," Reflective Cracking in Pavements, Proc. of the Third International RILEM Conference, pp. 456~463.

Kim, N., Park, Y., and Hwang, S. 1999, "A Study on Behavior of Rubber-Modified Asphalts", Journal of the Korea Society of Civil Engineering Vol.19, No.III-5, pp 873-885

Koerner, R.M. 1992, "Polymeric Geogrid Utilization in Paved Roads," FHWA PB 92-189513, Final Report, 56 pp.

Komatsu, T., Kikuta, H., Tuji, Y. and Muramatsu, E. 1998, "Durability Assessment of Geogrid-reinforced Asphalt Concrete," Geotextiles and Geomembranes, Vol. 16. pp. 257~271.

Marienfeld, M.L. and Smiley, D. 1994, "Paving Fabrics : The Why and the How-to," Geotechnical Fabrics Report, June/July, pp. 24~29.

ACKNOLEDGEMENT

This research has been performed as a part of Advanced Highway Research Center Project funded by Korea Ministry of Science and Technology, Korea Science and Engineering Foundation.