

Evaluating Resistance of Hot Mix Asphalt to Reflective Cracking Using Geocomposites

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16. Abstract The Pennsylvania Department of Transportation has sponsored a project with Penn State to evaluate new or existing products to ensure satisfactory application and performance of these products. PennDOT Publication 447 contains those products that are approved for application in lower-volume local roads. The objective of this effort was to review and evaluate a specific product listed in Publication 447 under specification MS-0360-0019, Bituminous Fiber Reinforced Stress Absorbing Membrane Interlayer (SAMI). The work toward evaluation of this product included three parts: a literature review, site visits, and an assessment of current specification under Publication 447. Evidence to date indicates satisfactory performance of this material and it is recommended that SAMI remain in PennDOT Publication 447. Emphasis should be placed on sealing cracks wider than ¼ inch before application of SAMI. Field evaluation indicates that wide cracks, if not properly sealed, do migrate to the surface regardless of SAMI application.					
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INTRODUCTION

Placing a structural asphalt overlay atop existing pavements is one of the conventional methods used in pavement rehabilitation. However, reflective cracking in the new overlay has been a serious challenge associated with pavement rehabilitation. Reflective cracking involves the development of cracks in a new overlay that mirror the cracks and/or joints in the old, existing pavement. Traffic loading and environmental effects are the primary external causes of reflective cracking. A geocomposite interlayer combining a high-modulus geogrid with a lightweight, non-woven geotextile may help delay or reduce reflective cracking by providing reinforcement and strain relief. Quantification of the reinforcement will provide a better understanding of the effectiveness of this method and offer an opportunity to identify important factors that affect the reinforcing performance.

The use of geosynthetics in pavements is not new. It has been used for drainage, separation layers, subgrade reinforcement, and other applications. As the focus of state highway agencies has shifted to rehabilitation and improvement of infrastructure, there is an ever growing need to develop and use advanced technologies and materials to extend the service life of rehabilitated roadways and their safety. Additionally, with the current trends toward energy conservation, enhanced environmental stewardship, sustainability, and budget tightening, the amount of asphalt and concrete mixtures used in pavements needs to decrease.

Geosynthetic-geogrid composite layers offer a unique solution to reinforce the asphalt pavements. This is a technology that has not yet been adopted. It promises significant savings in the amount of asphalt and concrete used for pavement construction. The products are still in the research and development phase and have not yet been implemented by state highway agencies.

This study, the results of which are presented herein, was conducted to evaluate the effectiveness of using a geocomposite interlayer to improve pavement performance, specifically in terms of resistance to reflective cracking. The study was carried out in two phases to evaluate the behavior of asphalt concrete overlaying rigid pavement or flexible pavement. In Phase I, performance of asphalt concrete overlaying hydraulic cement concrete was evaluated, with and without the inclusion of geocomposite. The second phase included an experiment with only asphalt concrete as both bottom and top layers of the pavement system. First, materials used in the study are introduced, followed by test equipment and test procedures. This is followed by an explanation of the experiments conducted in Phases I and II and discussion of results.

MATERIALS USED IN THIS RESEARCH

Materials used can be classified into two major groups: those for the asphalt overlays and those for constructing the concrete slabs serving as the base of the asphalt overlay. In addition, for each testing configuration (details of which are discussed later), a special kind of tack coat, known as FastTack®, was applied to the surface of each concrete slab at least 2 hours before placement of the asphalt layer over the concrete slab. Tacking was applied to achieve better bonding between the concrete slabs and the asphalt overlay. In Phase II of the project, the tack was also applied to the surface of the neoprene pad when asphalt was compacted in direct contact with the pad.

Materials for Asphalt Overlay

The materials for the 2-inch-thick asphalt overlay were hot-mix asphalts (HMA) procured from local asphalt mixing plants where local aggregate batches were mixed with a PG64-22 asphalt binder. Due to the limited amount of HMA that could be provided by each mixing plant, there were two different hot-mix asphalts from two local mixing plants used in this research. The first mix, designed based on the Marshall procedure, was used in the first testing configuration (for both control and geocomposite setups). The second mix, designed based on the Superpave system, was used for the second testing configuration (for both control and geocomposite setups). The mix design information for these two mixes can be found in Appendices A and B. This second mix was also used during the second phase of the study.

Materials for Concrete Slab

The concrete slabs in this study were constructed with four ingredients: water, cement, coarse aggregates, and fine aggregates. Both the coarse and fine aggregates were obtained from sources in central Pennsylvania. All slabs were cured for at least 28 days in order to achieve maximum strength before asphalt was placed and compacted on the top of the slab. The mix designs of the concrete slabs in different thicknesses are provided in Tables 1-3.

Table 1 Mix design for a 2-inch concrete slab.

Mix design for a 2-inch slab	Values given in pounds	
Volume of the slabs in cubic inches	928	
Volume of the slabs in cubic yard	0.01989168	
	1 Cubic Yard	Designed Weight
Water	344.8	6.9
Cement	666.7	13.3
Coarse aggregate	1645.2	32.7
Fine aggregate	1180.2	23.5

Table 2 Mix design for a 3-inch concrete slab.

Mix design for a 3-inch slab	Values given in pounds	
Volume of the slabs in cubic inches	1392	
Volume of the slabs in cubic yard	0.02983752	
	1 Cubic Yard	Designed Weight
Water	344.8	10.3
Cement	666.7	19.9
Coarse aggregate	1645.2	49.1
Fine aggregate	1180.2	35.2

Table 3 Mix design for a 4-inch concrete slab.

Mix design for a 4-inch slab	Values given in pounds	
Volume of the slabs in cubic inches	1856	
Volume of the slabs in cubic yard	0.03978336	
	1 Cubic Yard	Designed Weight
Water	344.8	13.7
Cement	666.7	26.5
Coarse aggregate	1645.2	65.5
Fine aggregate	1180.2	47.0

TESTING EQUIPMENT

The One-Third Scale Model Mobile Load Simulator (MMLS3) testing equipment used for the project was comprised of three parts: the MMLS3 loading unit, the air conditioner, and the electronic profilometer. The device is located at Penn State's Civil Infrastructure Testing and Evaluation Laboratory (CITEL).

The MMLS3, shown in Figure 1, is an accelerated pavement testing device that applies unidirectional trafficking to the pavement in a controlled laboratory environment or on full-scale pavements in the field. The MMLS3 has four tires, each with diameter of 12.0 inches and width of 3.1 inches. The actual wheel path generated by the MMLS3 is about 54 inches long. The load exerted by each wheel of the MMLS3 is 225 lbf with a corresponding tire pressure of 90 psi. The traffic speed was set to 7,200 axles (wheels) per hour, or two axles (wheels) per second.

The air conditioner and environmental chamber in Figure 2 were used to maintain the temperature inside the chamber while testing. The air conditioner can send cool or hot air at a specified temperature into the insulated environmental chamber through two air hoses. A thermocouple connected to the air conditioner on one side can measure the air temperature inside the chamber and send feedback to the air conditioner to adjust the air temperature.

For measuring the transverse surface profile, the electronic profilometer, presented in Figure 3, was used. During profiling, the meter was supported by two metal racks on both sides of the test set-up. The profilometer was connected to a computer to save the surface profile readings.

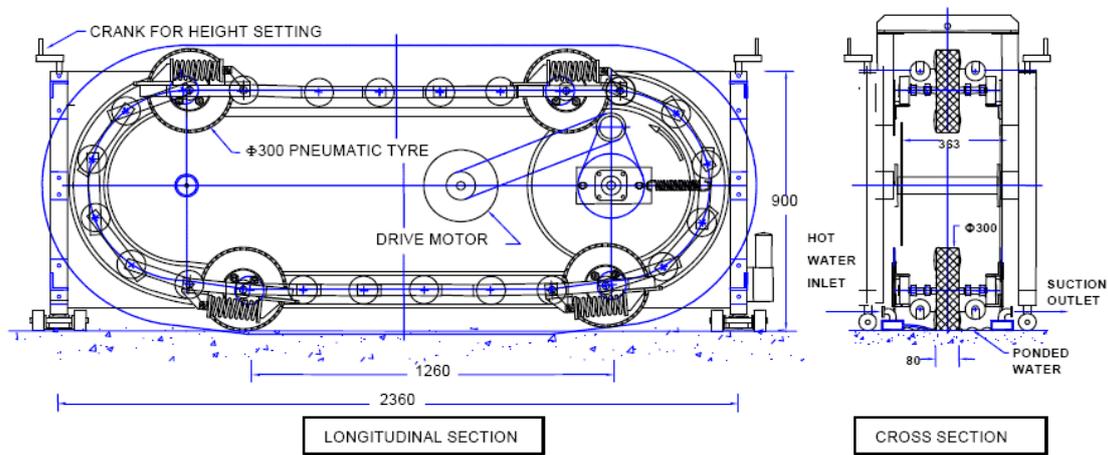


Figure 1 Schematic of MMLS3.

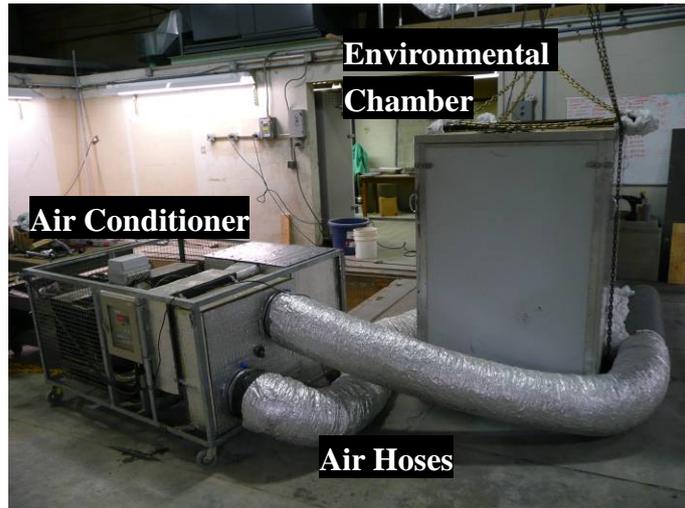


Figure 2 The air conditioner and environmental chamber.

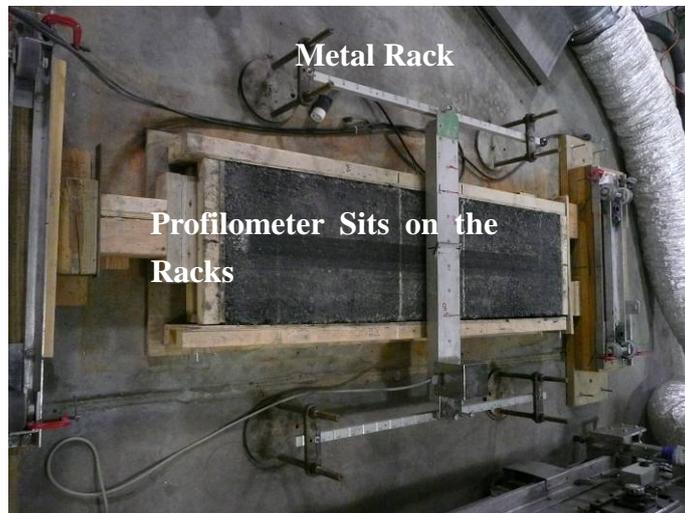


Figure 3 The profilometer.

EXPERIMENTAL PROGRAM

The experiment was conducted in two phases. In Phase I, the performance of asphalt concrete overlaying hydraulic cement concrete was evaluated, with and without inclusion of geocomposite. The second phase included an experiment with only asphalt concrete as both bottom and top layers of the pavement system. Overall, a total of 6 slabs were prepared and tested: 4 slabs under Phase I, and two under Phase II. Table 4 provides a summary of the testing program.

Table 4 Summary of testing program.

Slab #	Bottom Layer	Top Layer	Used Geocomp.?	When Slab Made	Foundation for Slab	When Slab Tracked With MMLS3	# of Load Cycles X1,000
1	Concrete at two thickness levels: 3" and 2". 2" layer sitting on 1" thick Neoprene	2" Asphalt	Yes	Aug. 2009	Lab. Concrete Floor	Sep. 2009	425
2	Concrete at two thickness levels: 3" and 2". 2" layer sitting on 1" thick Neoprene	2" Asphalt	No	Sep. Oct. 2009	Lab. Concrete Floor	Oct. 2009	425
3	4" thick Concrete sitting on 1" Neoprene	2" Asphalt	No	Oct. Nov. 2009	Lab. Concrete Floor	Nov. Dec. 2009	1,000
4	4" thick Concrete sitting on 1" Neoprene	2" Asphalt	Yes	Oct. Nov. 2009	Lab. Concrete Floor	Dec. 2009 Jan. 2010	1,000
5	2" Asphalt on 2" Neoprene	2.5" Asphalt	No	Nov. 2011	Part 1: Lab. Concrete Floor Part 2: Subgrade soil at CITEL pit	Dec. 2011	625
6	2" Asphalt on 2" Neoprene	2.5" Aged Asphalt	No	Jan. 2012	Subgrade soil at CITEL pit	Jan. 2012	510

Phase I

There were two testing configurations. Each configuration contained two setups, the control setup without geocomposite, and the experimental setup with a layer of geocomposite at the interface of the concrete slab with the asphalt overlay. Even though the length and the height of each configuration varied, the width stayed the same, 16 inches. Each configuration provided a surface for the MMLS3 to apply trafficking loads on the overlay and form a wheelpath. Testing temperature was targeted at 20°C. This temperature was selected to expedite crack initiation. Testing was conducted under dry conditions (i.e., no water was induced into the system). Furthermore, no wandering was allowed and trafficking was channelized.

First Testing Configuration

Figures 4 and 5 show the cross-sectional and dimensional plots of the two setups of the first testing configuration. The underlying concrete slab consisted of two adjacent sections (slabs). One section was 3 inches thick and placed directly on firm ground. The other section was 2 inches thick with a 1-inch-thick neoprene pad underneath. The idea supporting this set-up was to aggravate vertical movement at the joint expediting reflective cracking. Differential movement at the joint could also induce higher shear stresses at the asphalt section right on the joint. However, the experiment did not support this assumption. After loading with MMLS3, cracking at joint was noticed, initiating at the top and migrating downward due to the imposed cantilevered condition.

1st Test Setup of the 1st Testing Configuration

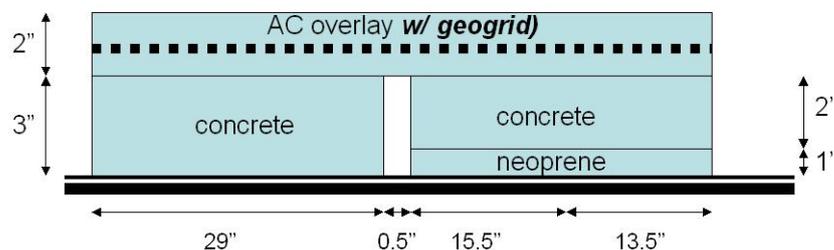


Figure 4 First setup of the first configuration (geogrid placed in between asphalt overlay).

2nd Test Setup of the 1st Testing Configuration

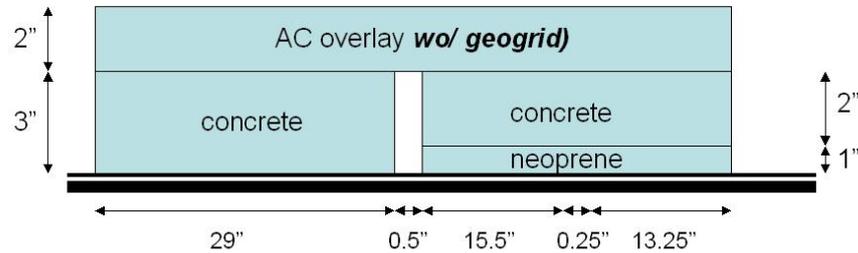


Figure 5 Second setup of the first configuration
(asphalt overlay without geogrid).

Second Testing Configuration

Figures 6 and 7 show the cross-sectional and dimensional plots of the two setups of the second testing configuration. In this configuration, concrete slabs were made 4 inches thick with rebars in order to prevent any damage to the slabs during the asphalt overlay compaction. Also, beneath each of the 4-inch concrete slabs was a 1-inch-thick neoprene pad. The purpose of the design in this configuration was to simulate the reflective crack that happens from the bottom of the asphalt overlay in the field. The joint between the two concrete slabs was increased from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch to increase the possibility of cracking.

1st Test Setup of the 2nd Testing Configuration

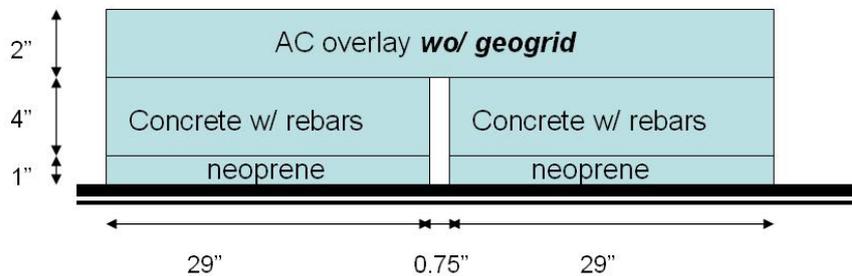


Figure 6 First setup of the second configuration
(asphalt overlay without geogrid).

2nd Test Setup of the 2nd Testing Configuration

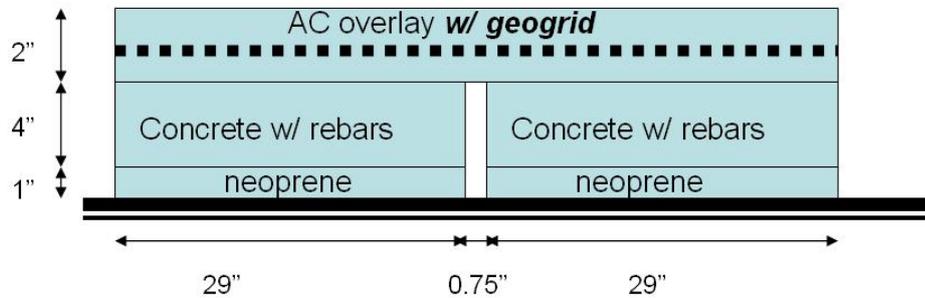


Figure 7 Second setup of the second configuration (geogrid placed in between asphalt overlay).

MMLS3 Testing Protocol

Each setup from both types of testing configurations was placed properly so that the tires of the MMLS3 could travel directly at the center strip of each setup. A total of three measurements were made on three locations of each setup, as shown in Figure 8. The first and third measurements were 6 inches away from the second measuring position, which was at the joint.

Positions for Profile Measurement

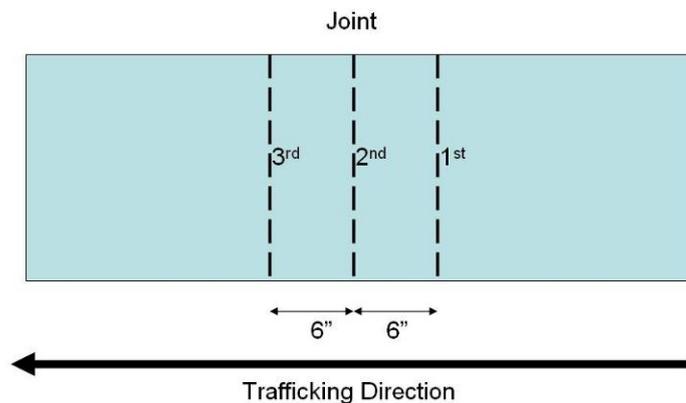


Figure 8 Three profile-measuring positions.

For the first testing configuration, a total of 400,000 trafficking cycles were applied for both setups. Tracking the permanent deformation in the asphalt overlay was achieved using transverse profile measurements at the load cycles presented in Table 5.

Table 5 Cycles at which transverse profile measurements were conducted (X 1,000).

10	20	50	100	150	200	250	300	350	400
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In addition, between 100,000 and 400,000 cycles, each test setup was examined for any sign of crack development every 25,000 cycles.

For the second testing configuration, a total of 1 million trafficking cycles were applied to both control and experimental setups. Before getting to 400,000 cycles, the profile was measured in the same manner as mentioned above. After 400,000 cycles, the profile measurements were done according to Table 6.

Table 6 Cycles at which transverse profile measurements were conducted after 400,000 level (X 1,000).

450	500	600	700	800	900	1,000
-----	-----	-----	-----	-----	-----	-------

Results and Discussion

Compaction Challenge

Compaction of the asphalt overlay on the top of the concrete slab was not conducted as smoothly as originally expected. For the first configuration, compaction caused transverse cracks at the bottom of the concrete slab at a distance from the joint. Originally, it was thought that such cracking was the result of MMLS3 tracking, as such cracks were observed in a previous test after MMLS3 loading. However, for the slabs of the first configuration, the integrity of the concrete slab was investigated before initiation of MMLS3 loading, and that is when cracks were observed. For the second configuration with thicker concrete slab and introduction of rebars, such cracking did not occur.

Temperature Challenge

This experiment was intended to be conducted in a controlled temperature environment. The target temperature was selected as 20°C. Maintenance of this precise temperature at all times was not achieved, but the temperature was kept within 18 to 22°C most of the time. For the second configuration, during the second phase of trafficking beyond 400,000 load cycles,

the temperature control unit did not function effectively, and the ambient temperature governed the testing.

Crack Observation

As mentioned previously, the asphalt overlay was investigated for signs of distress and cracking at specific cycle intervals. For the first configuration, the control setup without using geocomposite exhibited top-down cracking at the vicinity of the joint after experiencing 20,000 trafficking cycles, while the experimental setup with geocomposite in the overlay showed top-down cracking at similar position after 150,000 cycles. The crack width for both setups was almost the same, and approximately 0.3 to 0.4 mm. Figures 9 and 10 exhibit the surface condition of the slabs after 400,000 cycles of trafficking.

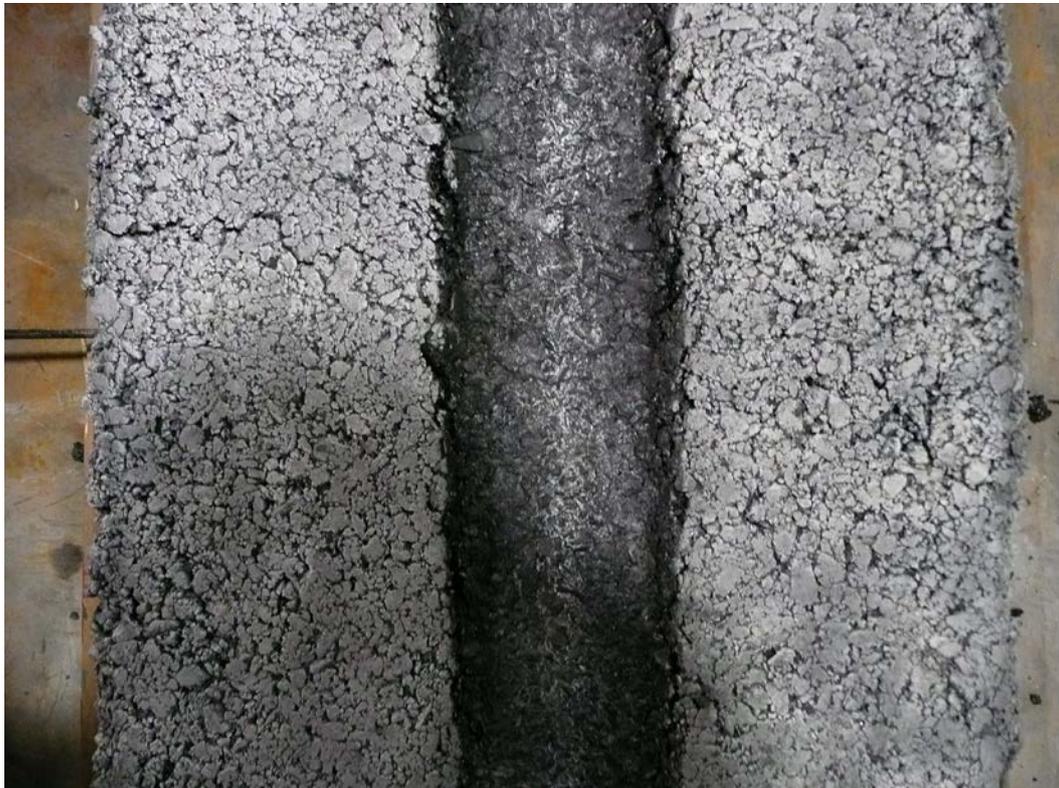


Figure 9 Crack at the middle joint position for the control setup of the first configuration after 400,000 trafficking cycles.



Figure 10 Crack at the middle joint position for the experimental setup of the first configuration after 400,000 trafficking cycles.

For the second configuration, no sign of cracking was detected. Loading of the slab was continued to 1 million cycles, significantly beyond the load level applied to the first configuration.

Results of Rutting of the Asphalt Overlay

Table 7 and Figure 11 show the rutting magnitude for all setups from both testing configurations. It can be seen that, for the first testing configuration, up to 150,000 cycles, the rutting levels are comparable and no significant difference is observed. After 150,000 cycles, a significant increase was observed in the rutting level of the setup with no geocomposite. While the usage of geocomposite might have helped in reducing the development of rutting, the significant increase in the setup with no geocomposite could be because of support removed at 150,000 cycles. Unfortunately, exact comparison is not possible because for the second setup (i.e., the one with no geocomposite), with resumption of loading after 150,000 cycles, the wooden supports at the sides were not placed back and this support removal certainly caused an increase in the rutting level. At the time, removal of supports was conducted just for the sake of convenience, not accounting for the potential significant impact of this action on the mat

deformation. For the second configuration (i.e., with uniform thickness of concrete slab), no significant difference was observed in the rutting levels between the system with geocomposite versus the system without geocomposite.

Table 7 Summary of rutting for all setups (grey areas denote unreasonable values).

	1st configuration with different concrete slab thickness (2"and 3"; wo/rebars)						2nd configuration with the same concrete slab thickness (4") w/rebars					
	1st setup w/Geocomposite			2nd setup wo/Geocomposite			1st setup wo/Geocomposite			2nd setup w/Geocomposite		
Cycles	1st position	2nd position	3rd position	1st position	2nd position	3rd position	1st position	2nd position	3rd position	1st position	2nd position	3rd position
X1,000	rutting, mm	rutting, mm	rutting, mm	rutting, mm	rutting, mm	rutting, mm	rutting, mm	rutting, mm	rutting, mm	rutting, mm	rutting, mm	rutting, mm
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	1.82	1.92	1.22	1.01	1.39	1.47	1.68	1.87	0.97	0.63	1.49	0.87
20	1.57	1.56	0.64	1.14	1.65	1.72	1.97	2.21	1.30	0.72	2.72	0.93
50	2.75	4.13	2.46	15.22	22.35	18.15	3.59	5.11	3.09	2.23	6.28	2.26
100	1.98	2.99	1.65	1.63	2.86	2.43	3.01	3.05	2.61	1.89	4.29	1.61
150	2.01	3.31	1.64	1.88	3.63	2.86	3.13	3.55	2.84	2.20	4.72	1.72
200	2.53	4.13	2.46	3.21	5.97	5.39	3.10	3.57	2.77	2.09	4.95	1.74
250	2.35	3.95	2.03	4.11	8.17	7.07	3.16	3.70	2.95	2.06	5.01	1.62
300	2.18	3.61	1.61	6.65	11.71	9.80	3.50	3.76	3.02	2.00	4.87	1.56
350	2.75	3.42	1.50	10.02	16.51	13.11	3.58	4.07	3.09	2.07	4.97	1.56
400	2.08	3.79	1.49	15.22	22.35	18.15	3.36	4.17	3.02	2.15	5.49	1.86
450	NA						3.53	4.27	3.02	1.98	5.18	1.51
500							3.54	4.31	3.08	1.95	5.20	1.54
600							3.57	4.43	3.06	2.22	5.53	1.57
700							3.51	4.73	3.09	2.16	5.29	1.43
800							3.48	4.74	3.06	2.18	6.28	1.56
900							3.59	4.84	3.01	2.23	5.65	1.53
1000							3.45	5.11	3.01	2.19	5.74	1.48

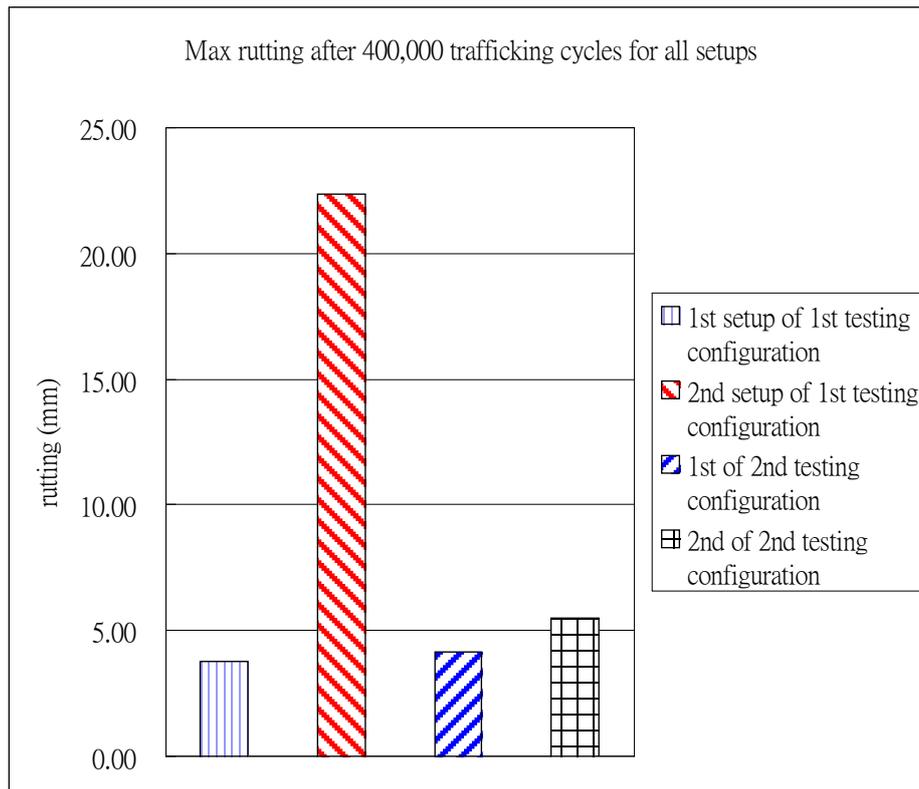


Figure 11 Max rutting for all setups after 400,000 trafficking cycles.

Phase II

In Phase II, the slab was made completely out of asphalt concrete overlaying neoprene. The experiment in Phase I demonstrated the great challenge that was encountered when inducing bottom-up reflective cracking in asphalt concrete using the MMLS3. As a result, in addition to the change in the underlying material from hydraulic cement concrete to asphalt concrete, a crack was induced in the bottom asphalt layer to expedite crack development. Furthermore, the neoprene thickness was increased from 1 inch to 2 inches to provide a deeper layer of softer foundation, which was sitting on the concrete floor. It was planned to carry out the experiment without geocomposite first, and move to the slab with geocomposite only after it had been possible to induce reflective cracks in the control section. Unfortunately, cracking could not be induced under various configurations of Phase II without expanding the unsupported span under the slab to a large extent; therefore, this phase of the study did not include any testing with geocomposite.

Control Slab #1

Figures 12 and 13 show the cross-sectional and dimensional plots of the first testing configuration under Phase II. The asphalt overlay was 2.5 inches thick bonded to the underlying asphalt concrete, which was 2 inches thick, with a vertical groove 0.5 inches wide.

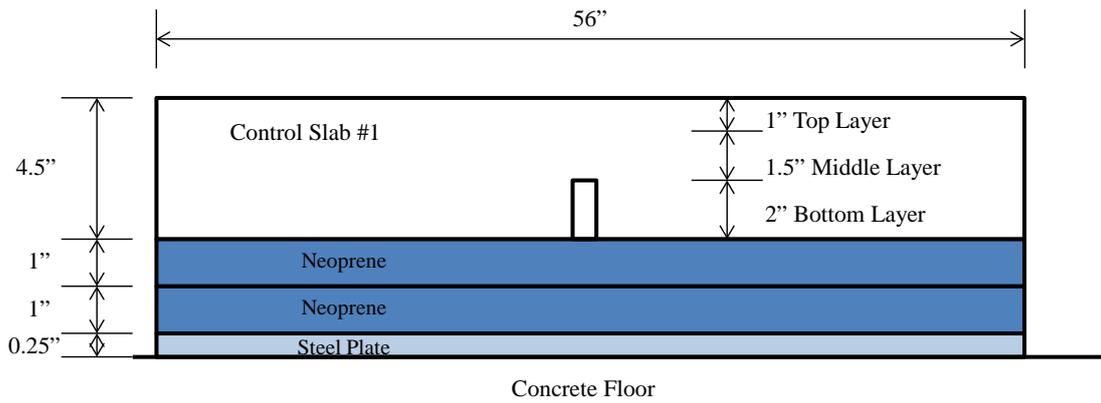


Figure 12 Configuration for slab #1 of Phase II during the first 400,000 loading cycles.

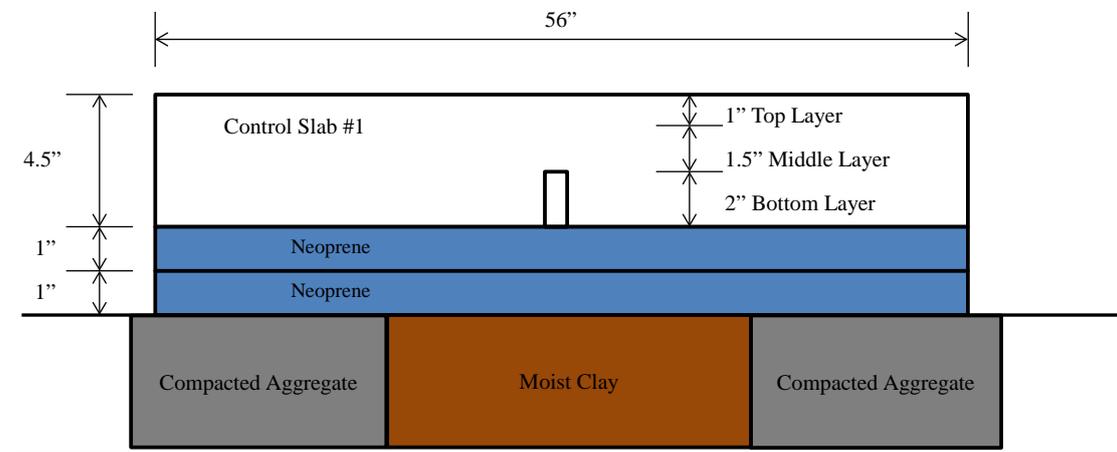


Figure 13 Configuration for slab #1 of Phase II during between 400,000 and 650,000 loading cycles.

Sample Preparation for Slab #1 of Phase II

For the first control slab, a wooden mold with internal dimensions of 56 inches in length, 25.5 inches in width and 5 inches of depth was used, all on top of a ¼-inch-thick steel plate. Two 1-inch layers of neoprene with Shore hardness of 60 were used in the bottom of the mold. With the neoprene in the mold, it was not deep enough for the slab, so additional wood was used to make the mold 6.5 inches deep.

Before compacting the bottom layer of the first control slab, a thin coating of fast curing tack was applied to the neoprene to help prevent the HMA from moving while compacting (Figure 14). A small piece of wood ½ inch thick by 2 inches tall was screwed inside the mold in the center, and in the horizontal direction, to replicate a joint crack.



Figure 14 Control slab #1 of Phase II after tack coat application.

The HMA was acquired from HRI Inc., a standard Superpave 9.5-mm mix design. The bottom layer was compacted to a thickness of 2 inches using an Ingersoll Rand Single Drum Vibratory Roller, model SX-170H. The roller weighs 780 lb and produces a compaction force of 2,000 lb, at 4,460 vibrations per minute. The roller's drum width is 18 inches and has a maximum compaction depth of 9 inches (Figure 15). After the bottom layer was cool, the piece of wood was removed to form the joint crack, and the crack was filled in with soft Styrofoam to prevent any hot-mix from filling in the crack during the compaction of the next layer.



Figure 15 Ingersoll Rand roller used for compacting samples.

Afterwards, the middle layer was compacted to a thickness of 1½ inches and the top layer was compacted to a thickness of 1 inch. All three layers were compacted using two passes of static rolling and ten passes of vibratory rolling. After the slab was cool, the sides

of the mold were removed and a white strip was painted on the vertical sides of the slab, along with a strip transversely across the slab directly above the man-made crack, to help in determining any cracking during trafficking.

Testing of Slab #1 of Phase II

The whole slab setup was moved to the area of the MMLS3, as seen in Figure 16. A series of gridlines were put on top of the slab in order to take PSPA (Portable Seismic Property Analyzer) readings and transverse profiles of the slab. The slab was tested with the two 1-inch layers of neoprene in place, on top of the ¼-inch-thick steel base plate, which sat on the concrete floor at CITEL.

PSPA readings and transverse profiles were taken before any trafficking was performed and at every stoppage of the MMLS3. The MMLS3 trafficking was performed and stopped at 10,000, 20,000, 50,000, 100,000, 150K, 200K, 250K, 300K, 350K, and 400K cycles. After 400K cycles of trafficking, there were no signs of cracking.



Figure 16 Slab setup in place before trafficking.

Since cracking could not be induced in the slab while trafficking on the concrete floor, the slab was moved into the test pit at CITEL by using a Bobcat Skid Steer. The Skid Steer used a forks attachment to move the slab into place and then the slab was slid off of the steel plate using the forks. The soil from the ends of the test pit was removed and replaced with aggregate to produce stiff supported ends of the slab and a weak center area under the slab. The center had a poor clay soil base with a moisture content of 24%, as seen in Figure 17.



Figure 17 Test pit with soil removed and soil replaced with aggregate.

After placing the slab and two 1-inch layers of neoprene in the test pit on top of the newly constructed test bed, trafficking resumed. The MMLS3 trafficking was performed at 5K, 10K, 15K, 20K, 25K, 25K, and 50K intervals for a total of 150K cycles while in the test pit. Since no cracking was seen on the slab, the enclosed environmental chamber for the MMLS3 was put in place on top of the MMLS3 and turned on and the temperature was set to 5°C. Several holes were drilled in the vertical side of the slab and thermocouples were placed at various depths to record the temperature of the slab during the last part of trafficking. The slab reached a low temperature of 8°C. An additional 100K load cycles were performed on the slab at this low temperature. The total number of cycles inside the test pit was 250K and the total overall was 650K. No cracking was observed after the 650K cycles. It was decided to stop trafficking and reevaluate the slab design for the next control sample slab. There were four core samples drilled from the slab, two from the wheel path and two from outside the wheel path. The core samples were tested for air void content, and the air voids range was from 10.6% to 11.7%, which was higher than expected. The target was 7.0% air voids after compaction.

Control Slab #2

As the first slab under Phase II did not show any cracking after 625,000 cycles, the decision was made to stiffen the asphalt mix through laboratory aging before compaction, and conduct the loading at a cooler temperature. Both aging and lowering of the temperature helped make the mix exhibit more brittle behavior in response to load. Figures 18 and 19 show the slab cross section and configuration at different loading stages.

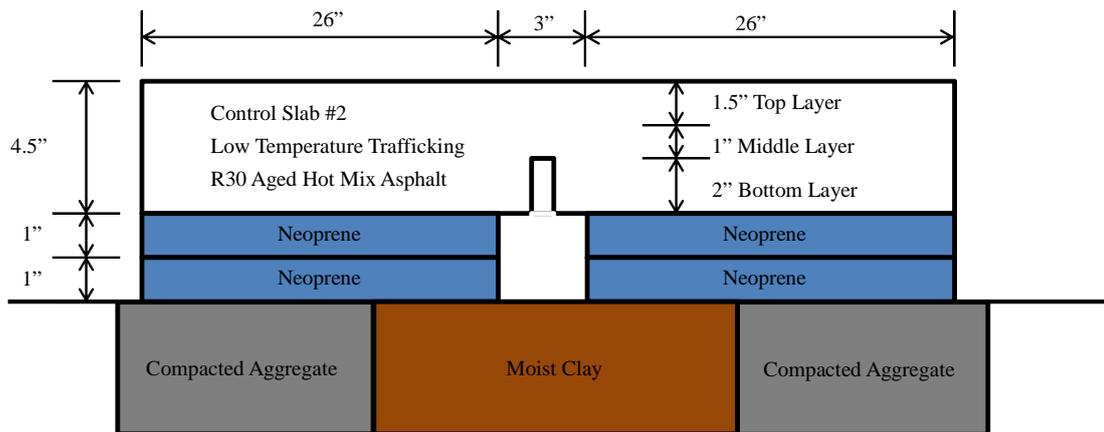


Figure 18 Configuration of slab #2 of phase II after 400,000 cycles to 465,000 cycles of load. During the first 400,000 cycles, the neoprene was continuous.

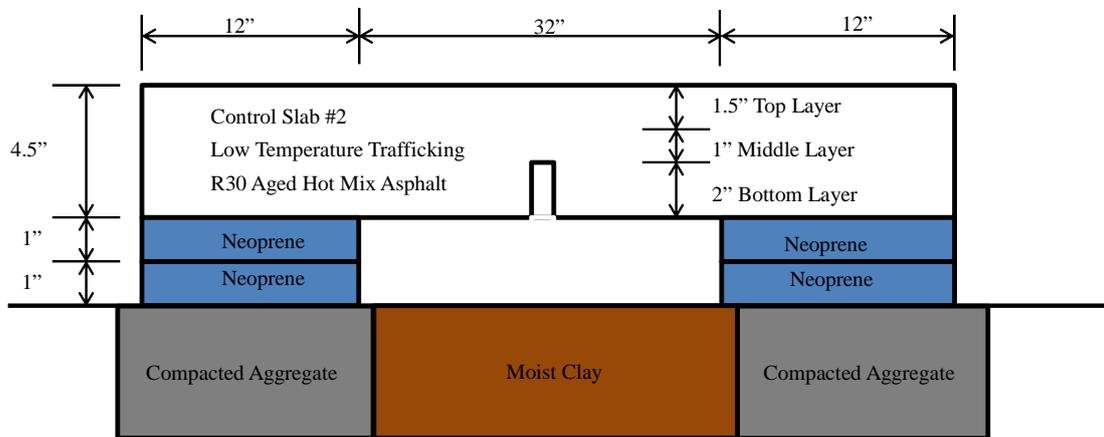


Figure 19 Configuration of slab #2 of phase II after 465,000 cycles to 510,000 cycles.

Sample Preparation for Slab #2 of Phase II

It was decided that the hot-mix asphalt to be used for the top layer of the second control slab of Phase II would be laboratory aged according to AASHTO R-30. To do this, six 5-gallon buckets of HMA were heated and split into trays and aged in ovens at 60°C for 7 days, according to AASHTO R-30 procedures. The same mold and neoprene were used to compact the slab. A thin layer of tack coat was applied again on the neoprene to help compaction of the bottom layer.

For this slab, it was decided that a piece of steel bar stock, ½ inch thick by 2 inches tall, would be used to induce the groove instead of the wood used in the last slab (Figure 20). The steel bar was kept in place for compaction of all three layers and then was removed when the slab was transferred to the test pit. The same HMA from HRI Inc. was used to construct the slab, but it was long-term aged for the top 2-inch layer. The same layer thicknesses were used from the previous slab. The same rolling pattern was used for compaction of the slab as for the previous. After compaction of all three layers, the slab was cooled to room temperature before transfer to the test pit. The wooden frame of the mold was removed and

a white strip was painted on the two vertical sides and along the top of the samples to help in the detection of cracks.



Figure 20 Second control slab with steel bar in place.

The moisture content of the clay base, taken before transferring the slab into the test pit, was 19%. The slab was then transferred into the test pit the same way as the previous slab using the Skid Steer with forks attachment. The two neoprene layers used under the slab were identical in size and matched the size of the slab, continuous with no separation. After the slab was transferred into the test pit, the MMLS3 was installed on top of the slab and the contact pressure was adjusted (Figure 21). Two small holes were drilled in the side of the slab and two thermocouples were glued into place to record the temperature of the slab during trafficking. Then the white environmental enclosure was set on top of the MMLS3 and any air spaces were filled in with tarps to prevent cold air from escaping during trafficking (Figure 22).



Figure 21 MMLS3 sitting on the asphalt slab in the test pit.



Figure 22 The MMLS3 and environmental enclosure.

The chiller unit was turned on and run for 24 hours before trafficking was started. At the start of trafficking the temperature of the slab was around 5°C. Trafficking was started and pictures were taken at every stoppage while looking for cracks. Trafficking was done in increments of 5K cycles for the first 25K cycles and then was performed at 15K-cycle increments for the rest of 375K cycles. After 190K cycles the slab temperature was above the desired testing temperature, so trafficking was stopped and the HVAC repair person was called to look at the chiller unit. The chiller unit had a small leak and was leaking coolant. The leak was repaired, but the chiller unit was still not achieving the desired cold temperatures. The repairman then noticed that the defrost cycle of the chiller unit was not working properly, so a new bypass valve was installed to turn on the defrost cycle every hour to melt any ice that was building up on the cooling coils inside the machine. This repair took several days, as can be seen on the temperature chart in Figure 23. Trafficking was resumed after the temperature of the slab was below 5°C and the final cycles were finished for a total of 400K cycles.

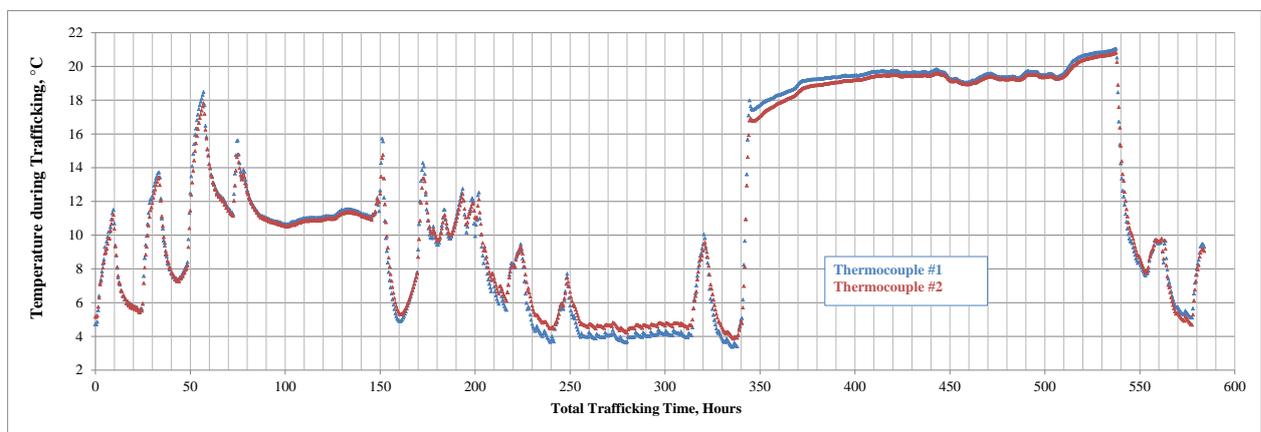


Figure 23 Temperature data during trafficking.

It was decided to remove the neoprene from the center of the slab, directly under the man-made crack and then continue trafficking (Figure 24). The full-size pieces of neoprene were removed from under the slab and were replaced with smaller pieces to create a 3-inch-wide gap directly under the man-made crack.



Figure 24 Photograph of the 3-inch gap under the slab.

An additional 15K cycles of trafficking was performed on the slab with the 3-inch gap under the slab with the enclosure removed to watch for cracking. After the 15K cycles of trafficking there were no signs of cracking. The slab then sat for 48 hours with the 3-inch gap, until it was decided to run another 50K cycles at 5°C. After the 50K cycles there were no signs of cracking. At this point, while this was not part of the study's testing plan, it was decided to widen the 3-inch gap to 32 inches to induce cracking. The neoprene from under the slab was again replaced with smaller sections to form a 32-inch gap under the slab, only having the neoprene 12 inches from each end (Figure 25). The slab sat overnight to cool back down to the test temperature of 5°C, and it was noticed the next morning that the slab layers had started to separate to the right of the man-made crack (Figure 25). The final 50K cycles of trafficking was started with the large section of slab being unsupported in the middle. It was noticed that the slab broke sometime before 45K cycles were completed (Figure 26). Three core samples were drilled from the slab, one from the wheel path and two from outside the wheel path, to determine the air voids. After testing the air voids, the core from the wheel path had an air void of 11.0%, and both cores from outside the wheel path had air voids of 11.6%.



Figure 25 Slab with 32-inch gap.



Figure 26 Slab after complete failure.

SUMMARY AND CONCLUSIONS

A study was undertaken to investigate the impact of using geocomposite to reduce reflective cracking in asphalt concrete overlays. The study was conducted in two phases: Phase I considered asphalt over concrete and Phase II examined asphalt over asphalt. In Phase I, two different configurations were used, one with two different thicknesses for underlying concrete slabs with the thinner side sitting on a neoprene foundation, and the other with uniform concrete slab thickness residing on a neoprene foundation. In both configurations, a 2-inch asphalt overlay was applied. Each configuration consisted of two different setups, one as the control system without geocomposite interlayer, and the other as the experimental system with geocomposite interlayer. The geocomposite was applied at the concrete-asphalt interface. The first configuration had a 0.5-inch spacing between the underlying concrete slabs. The second configuration had a 0.75-inch spacing. A total of four slabs were prepared under Phase I. The slabs for this testing resided on the laboratory concrete floor. Loading the asphalt overlay was conducted using an MMLS3 system. The first configuration experienced 400,000 cycles of MMLS 3 tire traffic load and the second configuration had 1,000,000 cycles of load. In none of the setups was bottom-up reflective cracking observed. However, it was clearly observed that under the first configuration, the geocomposite significantly improved the top-down cracking resistance of the asphalt overlay, as the system with no geocomposite manifested initiation of such cracking at 20,000 cycles and the system with geocomposite showed signs of top-down cracking at 150,000 cycles.

For the case of asphalt over asphalt (Phase II), two slabs were prepared without geocomposite. The first of these two slabs was first trafficked while sitting on the concrete floor and then moved to the test pit residing on the subgrade material for the remaining portion of trafficking. No cracking was observed. For the second slab of asphalt over asphalt, aged asphalt material was used in the test pit and testing was conducted at a cold temperature, but no cracking was developed after 465,000 cycles. Since no cracks could be induced in the slabs without geocomposite, testing was stopped and no slabs were prepared to include the geocomposite.

	JOB MIX FORMULA REPORT		SUPPLIER CODE	MATERIAL CLASS
	JMF NO.		HRI14A41	SP9.5
	2009	952	Design ESAL'S	.3 to <3
	Year	Number	AGGREGATE SRL	L
			ORIGINAL APPROVAL DATE:	3/1/01

DATE _____ SPEC 9.5mm PO _____

SUPPLIER NAME HRI INC. LOCATION Oak Hall, Pa Plant 101

BITUMINOUS PLANT TYPE AB TONS PER HOUR 120 ECMS NO. _____

Mix Time	
Dry	Wet
7	35

SR & SEC _____ CONTRACTOR _____ LOCATION _____

Material Supplier Code	Material Code	Material Class	% In Mix	Bulk Sp. Gr.	% Absorption
HAP14B14	207	B-3(W)	18.5	2.642	0.96
HAP14B14	207	B-3(D)	27.7	2.655	0.66
HAP14B14	207	B-3(A.S.)	6.6	2.677	0.78
HAP14B14	203	A8	41.5	2.703	0.54
UNRCO	1	64-22	5.7	1.029	
NUST1					
VALR1					

JOB MIX FORMULA AND DESIGN

AC %	.075 mm	.150 mm	.300 mm	.600 mm	1.18 mm	2.36 mm	4.75 mm	9.5 mm	12.5 mm	19 mm	25 mm	37.5 mm	50 mm	F/A	Pbe
Design	#200	#100	#50	#30	#16	#8	#4	3/8	1/2	3/4	1	1 1/2	2		
5.7	5.5	7.0	10	17	27	44	62	96	100	100	100	100	100	1.00	5.4
% Virgin AC	%		% Reclaimed AC												

MIX CHARACTERISTICS (Gyratory)

Gyrations @ Nini	Gyrations @ Ndes	Gyrations @ Nmax	Design ESAL's	Combined Agg Gravity Gsb	Max Density Gmm	Ndes Density Gmb
7	75	115	.3 to <3	2.675	2.472	2.373
% Voids @ Nini	% Voids @ Ndes	% Voids @ Nmax	% VMA @ Ndes	% VFA @ Ndes	Lbs / Cu. Ft.	Specimen Wt
14.7	4.0	2.7	16.3	75.5	154.3	4720.0

IGNITION FURNACE DATA

Oven Make	Set Temp.	Sample Size	AC Correction Factor	#200 Correction Factor
GILSON	538	1200.0	0.30	0.1

TSR DATA

AC Supplier	Dry PSI Strength	Wet PSI Strength	TSR Value	Date TSR's were done	Date of Boil Test
UNRCO	115.6	112.6	97.4	Bull.27 ch. 3 4-5-09	

Combined Aggregate Consensus Properties

AASHTO T176 Sand Equivalent	AASHTO T304 Uncompacted Void Content	ASTM D5821 Coarse Aggregate Angularity	ASTM D4791 Flat & Elongated
65.4	45.4	100	1.5

GRADATION CHART IS PART OF THIS JOB MIX FORMULA

Designed by Richard Weaver Necept #6 Date 03/28/09

Approved and Submitted by Richard Weaver Date 3-28-09

Reviewed by District Materials Engineer [Signature] Date 4/20/09

Page 1 CCR 4-16-09
RM

Manual Entry

TR-448A (11-14-08) 	JOB MIX FORMULA REPORT		SUPPLIER CODE	MATERIAL CLASS
	JM F NO.		HRI14A41	SP9.5
	2009 Year	951 Number	Design ESAL'S	<0.3
			AGGREGATE SRL	L
			ORIGINAL APPROVAL DATE:	3/1/01

DATE _____ SPEC 9.5mm PO _____

SUPPLIER NAME HRI INC. LOCATION Oak Hall, Pa Plant 101

BITUMINOUS PLANT TYPE AB TONS PER HOUR 120 ECMS NO. _____

Mix Time	
Dry	Wet
7	35

SR & SEC _____ CONTRACTOR _____ LOCATION _____

Material Supplier Code	Material Code	Material Class	% In Mix	Bulk Sp. Gr.	% Absorption
HAP14B14	207	B-3(W)	18.4	2.642	0.96
HAP14B14	207	B-3(D)	27.6	2.655	0.66
HAP14B14	207	B-3(A.S.)	6.6	2.677	0.78
HAP14B14	203	A8	41.3	2.703	0.54
UNRCO	1	64-22	6.1	1.029	
NUST1					
VALR1					

JOB MIX FORMULA AND DESIGN

AC %	.075 mm	.150 mm	.300 mm	.600 mm	1.18 mm	2.36 mm	4.75 mm	9.5 mm	12.5 mm	19 mm	25 mm	37.5 mm	50 mm	F/A	Pbe
Design	#200	#100	#50	#30	#16	#8	#4	3/8	1/2	3/4	1	1 1/2	2		
6.1	5.5	7.0	10	17	27	44	62	96	100	100	100	100		1.00	5.8
% Virgin AC	%		Reclaimed AC												

MIX CHARACTERISTICS (Gyratory)

Gyrations @ Nini	Gyrations @ Ndes	Gyrations @ Nmax	Design ESAL's	Combined Agg Gravity Gsb	Max Density Gmm	Ndes Density Gmb
6	50	75	<0.3	2.675	2.457	2.359
% Voids @ Nini	% Voids @ Ndes	% Voids @ Nmax	% VMA @ Ndes	% VFA @ Ndes	Lbs / Cu. Ft.	Specimen Wt
14.4	4.0	2.9	17.2	76.7	153.3	4750.0

IGNITION FURNACE DATA

Oven Make	Set Temp.	Sample Size	AC Correction Factor	#200 Correction Factor
GILSON	538	1200.0	0.30	0.1

TSR DATA

AC Supplier	Dry PSI Strength	Wet PSI Strength	TSR Value	Date TSR's were done	Date of Boil Test
UNRCO	115.6	112.6	97.4	Bull.27 ch. 3 4-5-09	

Combined Aggregate Consensus Properties

AASHTO T176 Sand Equivalent	AASHTO T304 Uncompacted Void Content	ASTM D5821 Coarse Aggregate Angularity	ASTM D4791 Flat & Elongated
65.4	45.4	100	1.5

GRADATION CHART IS PART OF THIS JOB MIX FORMULA

Designed by Richard Weaver Necept # 6 Date 03/28/09

Approved and Submitted by Richard Weaver Date 3-28-09

Reviewed by District Materials Engineer at a Jimi Date 7/29/09

TR-49A(4-98) Dist. 2-0 Revision	JOB MIX FORMULA REPORT	Supplier Code H R I 1 4 A 4 1	Material Class I D 2 W
JMF No. 0 5 1 2 0		AGGREGATE SRL L	

Date _____ Spec. ID-2Wearing SRL "L" Tons _____ P.O. _____

Suppliers Name: HRI INC. Location: Oak Hall, PA Plant 101

Bituminous Plant Type: Batch Daily Capacity: 1200 ton / 1089 tonnes Mix Time

Dry	Wet
7	35

CMS No. _____ SR _____ Sec. _____

Aggregate Supplier Code	Material Code	Material Class	% In Mix	Bulk Sp. Gr.	% Absorption
HAP14B14	207	B3 (W)	34.2	2.640	0.97
HAP14B14	207	B3 (D)	14.7	2.651	0.76
HAP14B14	203	A8	45.3	2.701	0.39
PG Producer Code	Material Code	PG Grade	% In Mix	Rotational Visc @ 165 C / 135 C	
UNRC0	1	64-22	5.8	0.110	0.385
CHEV0	1	64-22			
CITG1	1	64-22			

JOB MIX FORMULA AND DESIGN

AC %	.075 mm #200	.150 mm #100	.300 mm #50	.600 mm #30	1.18 mm #16	2.36 mm #8	4.75 mm #4	9.5 mm 3/8"	12.5 mm 1/2"	19 mm 3/4"	25 mm 1"	37.5 mm 1 1/2"	50 mm 2"	F/A %	Pbe % Eff. AC	Uncomp. Voids FA
Design	5.8	5.5	8	10	17	27	45	62	95	100				N/A	5.4	N/A
% Virgin AC	5.8			% Reclaimed AC		N/A										

MIX CHARACTERISTICS (MARSHALL / GYRATORY)

Theor. Density	Lab Density	% Voids	% VFA	% VMA	Stability		Flow	% Pass #8 (2.36)	% Pass 1/2" (12.5)
					lbs.	Newtons			
2.472	2.355	4.7	72.4	17.1	2058	9297	9.8	45	100

MIX CHARACTERISTICS (GYRATORY)

Design EASLS	Gyrations @ N ini	Gyration @ N des	Gyrations @ N max	Max Density (kg/m3)/Sp.Gr.	Ndes Density (kg/m3)/Sp.Gr.
N/A	N/A	N/A	N/A	N/A	N/A
	% Voids@Nini	%Voids@Ndes	%Voids@Nmax		
	N/A	N/A	N/A		

IGNITION FURNACE DATA

Oven Make	Set Temp.	Sample Size	A.C. Correction Factor (Cf)	#200 Correction Factor (200Cf)
Gilson	540 C	1200 g	0.25	0.00

GRADATION CHART ON BACK IS PART OF THIS JOB MIX FORMULA

Designed by Richard Weaver Date 1-5-05
 Approved & Submitted by Richard Weaver Date 1-5-05
 Reviewed by Mat's Engineer John E. Smith Date 1/29/05

	JOB MIX FORMULA REPORT		SUPPLIER CODE	MATERIAL CLASS
	JMF NO.		HRI14B41	SR9.5
	2009 Year	3551C Number	Design ESAL'S	<0.3
			AGGREGATE SRL	M
			ORIGINAL APPROVAL DATE:	3/1/06

DATE _____ SPEC 9.5mm PO _____

SUPPLIER NAME _____ HRI INC. _____ LOCATION Curtin Gap Plant 103

BITUMINOUS PLANT TYPE AB TONS PER HOUR 350 ECMS NO. _____

Mix Time	
Dry	Wet
7	35

SR & SEC _____ CONTRACTOR _____ LOCATION _____

Material Supplier Code	Material Code	Material Class	% In Mix	Bulk Sp. Gr.	% Absorption
HAP14A14	207	B-3(W)	38.1	2.735	0.71
HAP14A14	207	B-3(A.S.)	7.4	2.756	0.91
HAP14A14	203	A8	34.5	2.771	0.76
NOBLT14	17	RAP	15.0	2.751	0.0
UNRCO	1	64-22	5.0	1.029	
NUST1					
VALR1					

JOB MIX FORMULA AND DESIGN

AC %	.075 mm	.150 mm	.300 mm	.600 mm	1.18 mm	2.36 mm	4.75 mm	9.5 mm	12.5 mm	19 mm	25 mm	37.5 mm	50 mm	F/A	Pbe	
Design	#200	#100	#50	#30	#16	#8	#4	3/8	1/2	3/4	1	1 1/2	2			
5.8	5.5	8.0	12	17	27	44	65	97	100					1.00	5.4	
% Virgin AC	5.0	% Reclaimed AC				0.8										

MIX CHARACTERISTICS (Gyratory)

Gyrations @ Nini	Gyrations @ Ndes	Gyrations @ Nmax	Design ESAL's	Combined Agg Gravity Gsb	Max Density Gmm	Ndes Density Gmb
6	50	75	<0.3	2.752	2.532	2.431
% Voids @ Nini	% Voids @ Ndes	% Voids @ Nmax	% VMA @ Ndes	% VFA @ Ndes	Lbs / Cu. Ft.	Specimen Wt
13.5	4.0	2.5	16.8	76.2	158.0	4820.0

IGNITION FURNACE DATA

Oven Make	Set Temp.	Sample Size	AC Correction Factor	#200 Correction Factor
GILSON	538	1200.0	0.22	0.3

TSR DATA

AC Supplier	Dry PSI Strength	Wet PSI Strength	TSR Value	Date TSR's were done	Date of Boil Test
UNRCO	204.6	184.5	90.2	1/25/09-Bull. 27 ch 3	

Combined Aggregate Consensus Properties

AASHTO T176	AASHTO T304	ASTM D5821	ASTM D4791
Sand Equivalent	Uncompacted Void Content	Coarse Aggregate Angularity	Flat & Elongated
92.9	47.1	100	1.3

GRADATION CHART IS PART OF THIS JOB MIX FORMULA

Designed by Richard Weaver Necept # 6 Date 08/03/09
 Approved and Submitted by Richard Weaver Date 8-3-09
 Reviewed by District Materials Engineer [Signature] Date 8/3/09