PRINTED BY: jose.aguiar@ucr.ac.cr. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

Advances in Materials and Pavement Performance Prediction – Masad et al. (Eds)
© 2018 Taylor & Francis Group, London, ISBN 978-1-138-31309-5

Testing and modeling geotextiles as reflective cracking attenuators

P. Leiva-Padilla, L.G. Loría-Salazar & J.P. Aguiar-Moya
National Laboratory of Materials and Structural Models of the University of Costa Rica, Costa Rica

ABSTRACT: This study shows results obtained from analyzing the mechanical behavior of nonwoven geotextiles as interlayer systems by means of laboratory tests and finite element modeling. As a result, a new methodology for evaluating geotextiles work as interlayer systems was proposed. A disassembled mold was designed to compact the specimens using a vibrating roller compactor. Specimens with a geotextile embedded at two-third depth from the top of the HMA layer were used in the study. A finite element model of the sample during testing was generated and validated to describe the work of the geotextile as an interlayer system. Test results showed the moment when geotextiles work as stress attenuator and as reinforcement during testing. To achieve the optimum stress attenuation work, it was probed that the geotextile should be placed in the compression zone of the Hot Mixture Asphalt (HMA) layer and should be adequately impregnated with enough emulsion.

1 INTRODUCTION

Reflective cracking is a fatigue process where cracks propagate from the existing HMA layer to the new HMA overlay. According to ASTM E1823-13 (ASTM, 1823): Standard Terminology Relating to Fatigue and Fracture Testing, fatigue is "*a process of progressive localized permanent structural change occurring in a material subjected to conditions that produce fluctuating stresses and strains at a point or some points and that may culminate in cracks or complete fracture after a sufficient number of fluctuations*".

Some of the most used techniques to delay reflective cracking in pavements are: increasing the overlay thickness, modifying the HMA overlay, using SAMIs (Stress Absorbing Materials Interlayers), rubblizing or cracking and seating the existing HMA layer pavement prior to place the new HMA overlay or using interlayer systems as for example geosynthetic materials (Jackson, 1980; Barksdale, 1991; Mukhtar and Dempsey 1996; Dempsey, 2002; Button & Lytton, 2015 and Hajj & Loria-Salazar, 2008).

According to the Scopus data base, research work in using geosynthetics as reflective cracking attenuators is a research topic with an increasing number of publications since 1988 (Figure 1). Geogrids, geotextiles and geocomposites are the most commonly used materials in this kind of applications.

Even though the amount of research in the field is big, there is still little gaps related to the work of the geotextile as a stress relief or a reinforcement material (Button and Lytton, 1987; Amini, 2005). The current paper proposes a methodology to study the performance mode of geotextiles as interlayer systems, by means of a flexure test configuration implemented in laboratory and a finite element model of it. This coupling between laboratory work and finite element modeling was chosen as an alternative to the complicated instrumentation of geotextiles. A valid FEM model allows predicting the real way geotextiles work in this kind of applications.

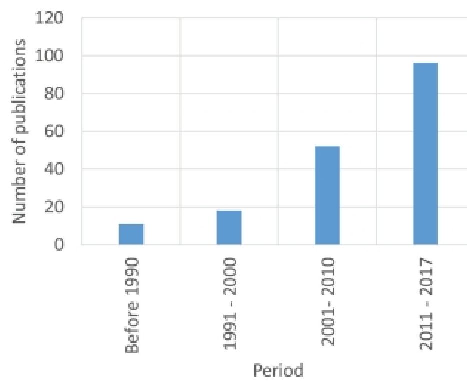

Figure 1. Scopus search related to: Reflective cracking and geosynthetics, based on publication period.

2 METHODOLOGY

2.1 *Materials and testing plan*

The HMA used in the project was sampled from a rehabilitation project in Costa Rica. The reha-

PRINTED BY: jose.aguiar@ucr.ac.cr. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

bilitation consisted in removing 70 cm of the existing asphalt concrete layer, then placing a geotextile and 70 cm of new HMA overlay.

Prony Series parameters obtained from the Dynamic Modulus test (ASTM D3497) were used to characterize the viscoelastic performance of the HMA (Table 1). The HMA was analyzed under two conditions: (1) field conditions and (2) aged in oven for 5 days at 60°C (to simulate existing HMA conditions during sample preparation).

In order to simulate the real compaction work in the field, a vibratory roller compactor and a specially designed mold were used to prepare the laboratory specimens (beams of 60 cm long, 15 cm height, and 15 cm wide). The specimen preparation process was carried out as follows (Figure 2):

Step 1: Compaction and aging (5 days at 60°C) of a 5 cm HMA layer (Figure 2c).

Step 2: Emulsion application and geotextile installation:

Table 1. HMA prony series.

Relaxation time	Aged HMA layer prony series parameters	HMA overlay prony series parameters
(s)	E_i (MPa)	E_i (MPa)
1E-05	3036	2658
1E-04	3499	3053
1E-03	3981	3454
1E-02	4436	3649
1E-01	4758	5056
1E+00	3248	816
1E+02	913	617

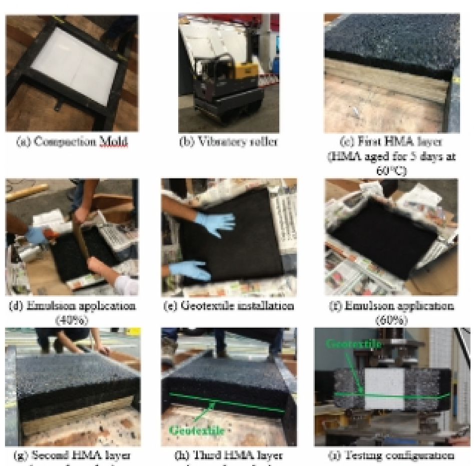

Figure 2. Specimen preparation process.

- Specimens + geotextile (Figure 2d,e,f): 1.1 l/m^2, 40% of the dosage applied before and 60% after the geotextile installation (based on manufacturer recommendations). The selected material is a nonwoven geotextile with 7.7 kN/m of tensile strength (ASTM D4595).
- Emulsion application methodology (Figure 2d,f): to represent the sprayer bar of the dealer truck on field, there was used a paint gun with an air pressure system regulated by a manometer. The paint gun was properly calibrated using its flow value and the dosage required. There was used a quick set (QS) emulsion. The new HMA overlay was placed until the emulsion changes its color, to guarantee the work with the residual asphalt and a proper adherence. Similarly to field conditions, those times were between 3 to 15 min.

Step 3: Compaction of two additional lifts of HMA (5 cm of thickness each, Figure 2 g,h). The geotextile was placed at two-third depth from the top of the HMA layer, to evaluate its maximum reinforcement capacity and providing some stress attenuation (to evaluate both functions). Under the neutral axis of the layer, the geotextile works as a membrane in tension, improving the modulus of the new overlay.

Step 4: Block cutting into three beam specimens perpendicular to roller compaction direction.

Step 5: Sample testing (Figure 2i). The following test configuration was used: (1) specimens with geotextile reinforcement, (2) sinusoidal load amplitude (stress dependent load = 9.0 kN with a 3.0 kN oscillation [enough to apply 1500 loading cycles], Frequency of load = 3 Hz), and (3) testing at room temperature (25°C, typical temperature value used in laboratory).

2.2 *Finite element modeling*

To properly study the performance of the geotextile during testing, a finite element model as defined in Figures 3 and 4 was analyzed.

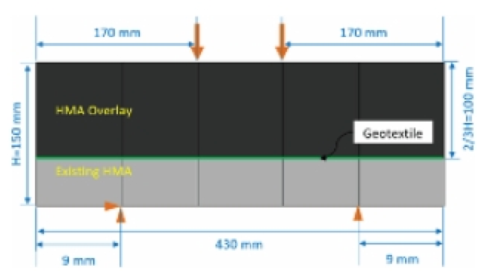

Figure 3. Model geometry (dimensions of the specimen: 430 mm × 150 mm × 100 mm).

PRINTED BY: jose.aguiar@ucr.ac.cr. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

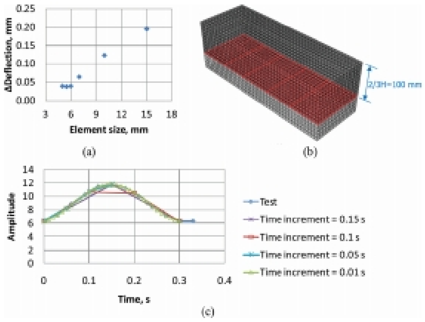

Figure 4. Model validation and definition: (a) element size convergence, (b) membrane elements, and (c) time increment convergence.

Table 2. FEM model validation.

Maximum load applied (kN)			Deflection (mm)		
Test	FEM	Error	Test	FEM	Error
11.502	11.718	2%	2.06	2.08	1%

The mesh and time convergence analysis was used to define 29,952 elements and a time increment of 0.01 s to represent the system.

Mechanical performance of the geotextile was considered by assigning membrane elements (Figure 4b in red color, M3D4R based on ABAQUS: membrane, three-dimensional, 4 nodes, and reduced integration elements) which are surface elements that only transfer loads in the plane. These elements do not transfer moments and do not have flexural stiffness. Considering that laboratory construction of the specimen was done carefully, a full contact between the geotextile surfaces and the surrounding HMA layers was assumed. Table 2 demonstrates (with an error ranging between 1% and 2% depending on the response variable) that the model is appropriate to represent the test. Values used in Table 2 correspond to the maximum values obtained during testing.

Different crack lengths were inserted in the model using seams as interface elements, to study the performance of the geotextile at different moments during testing. The instance of the model is divided where the seam is placed, because the seam gives a cero contact between the generated surfaces.

The seam pattern used was defined from patterns obtained on the real specimens after failure (Figure 5): first vertically until reach the geotextile and then horizontally following geotextile existing HMA layer. The existing HMA overlay was not notched to study the work of the geotextile since the initial stage when some parts of the existing HMA layer are still not cracked (that corresponds to the maximum possible work developed by the geotextile). Since seams are induced cracks, they do not consider any constitutive model at the interface. Then a model with a seam represents the moment when the crack had propagated the length defined by it.

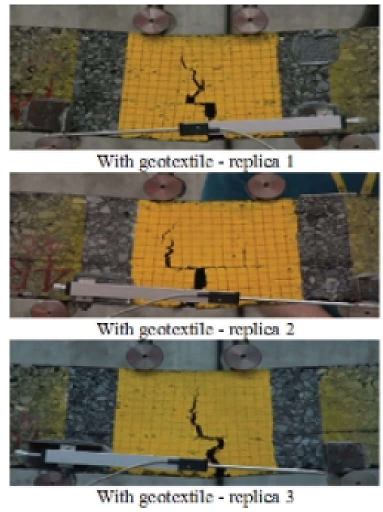

Figure 5. Crack pattern on the real specimens after failure.

3 RESULTS

Geotextiles can provide reinforcement support to the new HMA overlay when they develop tensile stresses under traffic loading. The vertical and the horizontal component of the tensile stresses developed by the geotextile are respectively associated with a membrane support and the lateral confinement of the new overlay (Figure 6).

To precisely define when the material provides membrane support or lateral confinement during testing, the horizontal and the vertical stresses developed by the geotextile were measured from the defined model, using different crack lengths (Figure 6).

Results show that the horizontal component of stresses developed by the geotextile produce an increment in the HMA overlay modulus. This horizontal component absorbs most of the work done by the geotextile, until a point where the crack is redirected from its previous vertical position in the existing pavement to follow the geotextile-overlay

PRINTED BY: jose.aguiar@ucr.ac.cr. Printing is for personal, private use only. No part of this book may be reproduced or transmitted without publisher's prior permission. Violators will be prosecuted.

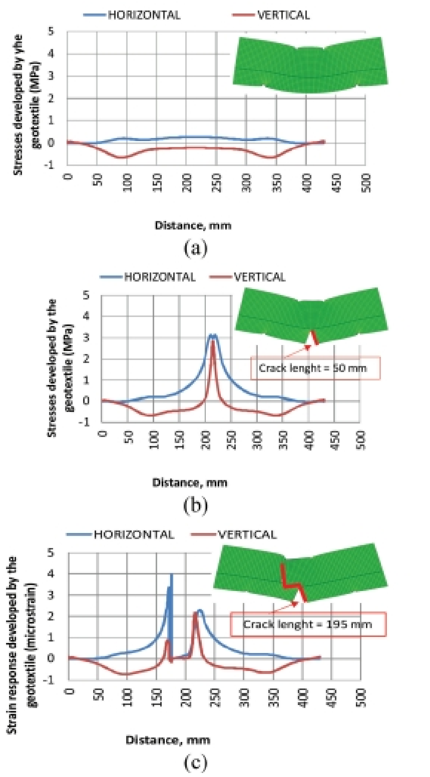

Figure 6. Horizontal and vertical stresses developed by the geotextile for a (a) 0 mm, (b) 50 mm, and (c) 195 mm crack.

interface (when the vertical component of tension stresses increase). Finally the crack propagates to the surface.

It is important to note that geotextiles do not have interlocking capabilities with aggregate: its reinforcement capacity is poor. Geotextiles should be used mainly as stress attenuator materials, due to their capacity to absorb stresses when they are adequately impregnated with emulsion and additionally they are placed above the neutral axis of the total HMA layer (allowing the movement of the underlying pavement).

4 CONCLUSIONS

This paper summarized the results obtained from analyzing the work done by geotextiles during flexural loading. Both, stress relief and reinforcement (through membrane and confinement stress tensile components) functions were described using a finite element model of the test.

When geotextiles are placed in the tension zone of the HMA layer, they work as a reinforcement material. The previous is mainly associated to the horizontal component of stresses developed by the geotextile, which generates a confinement effect in the HMA overlay, improving its modulus. However, due to the geometrical and the mechanical properties of geotextiles (absorbent material and low tension resistance in comparing to geogrids), the authors suggest that their use can be optimized if they develop a stress relief function, which is guaranteed when they are placed above the neutral axis of stresses and if they are adequately saturated with emulsion.

Ongoing work in this research project includes the improvement of the test configuration proposed, in order to consider the support of the underlying pavement layers. The test protocol is also being modified to account for changes in environmental conditions (temperature and moisture) and traffic solicitations to better account for field conditions.

REFERENCES

Amini, F. 2005. Potential Applications of Paving Fabrics to Reduce Reflective Cracking (No. FHWA/MS-DOT-RD-05-174). Jackson State University.

ASTM 1823 Standard Terminology Relating to Fatigue Testing.

ASTM D 4595. Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method. American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

Barksdale, R.D. 1991. Fabrics in Asphalt Overlays and Pavement Maintenance. *Transportation Research Board, Report No. NCHRP 171*, Washington, D.C.

Button, J., & Lytton, R. 1987. Evaluation of Fabrics, Fibers and Grids in Overlays. *Proceedings of the Sixth international conference on structural design of asphalt pavements (págs. Vol. 1, pp. 925–934)*. The University of Michigan.

Button, J., & Lytton, R. 2015. Guidelines for using geosynthetics with hot-mix asphalt overlays to reduce reflective cracking. *Transportation Research Record: Journal of the Transportation Research Board.*

Dempsey, B. (2002). Development and Performance of Interlayer Stress-Absorbing Composite in Asphalt Concrete Overlays. *Transportation Research Record: Journal of the Transportation Research Board 1809*, págs. 175–183.

Jackson, R.D. 1980. Use of Fabrics and Other Measures for Reflective Cracking of Alphabetic Concrete Overlays. *Final Report, Report No. WES/MP/GL-80-2, FAA/RD-80/8, Waterways Experiment Station, Corps of Engineers.* Vicksburg, MS.

Lytton, R. 1989. Use of geotextiles for reinforcement and strain relief in asphalt concrete. *Geotextiles and Geomembranes. Vol. 8, 217–237.*

Mukhtar, M., & Dempsey, B. 1996. Interlayer Stress Absorbing Composite (ISAC) for Mitigatiing Reflection Cracking in Asphalt Concrete Overlays. (No. UILU-ENG-96-2006).