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Geosynthetic Concrete Performance Analysis

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ABSTRACT

The seminar report "Geosynthetic Concrete" gives an extensive review of the application of geosynthetic materials to improve the performance and long-term durability of flexible pavements, especially hot mix asphalt (HMA) overlays. Flexible pavements make up approximately 94% of surfaced roads in the United States, and maintenance is essential due to rising traffic loads, weather effects, and budget limitations. Reflective cracking- cracks that propagate from underlying pavement layers because of load and temperature stresses-is a problem common to HMA overlays installed as thin layers to overlay pavements for their maintenance. Such overlays lead to a reduction in pavement service life and a boost in maintenance cost.

Geosynthetics as man-made fabric, grid, composite, or membrane installed on or below the earth have evolved as promising solutions to address reflective cracking. These products, usually polymers like polypropylene, polyester, or fiberglass, are placed between the original pavement and the overlay. They help strengthen the pavement structure by offering high tensile strength and stiffness, thus postponing crack initiation and growth. The paper classifies geosynthetics as fabrics (woven or nonwoven), grids (mesh-like geotextiles with rectangular openings), and composites (laminates of fabric and grid), each engineered to maximize adhesion and mechanical performance under overlay conditions.

Keyword : - Hot Mix Asphalt (HMA) Overlay, Geosynthetic Concrete, Pavement Maintenance. Reflective Cracking, Tensile Strength, Thermal Stress

1. INTRODUCTION

Flexible pavements, also known synonymously as asphaltic concrete or hot mix asphalt (HMA) pavements, are one of the chief elements involved with the construction of highway facilities and, currently, account for roughly 94 percent of surfaced highways in the United States. Two other significant classes of pavements are rigid, or portland cement concrete (PCC) pavements, and composite pavements made of a PCC pavement overlaid with an HMA pavement. For flexible and composite pavements, one of the most common methods practiced by most agencies for preventive maintenance and/or rehabilitation is merely to overlay a thin HMA, typically 1 to 2 inches thick.

The purpose of this is to shield the existing surface from water penetration, lower the roughness, bring back skid resistance, enhance structural capacity, and enhance the general ride quality to the traveling public. offer a very good overview of HMA overlay design methods that are widely practiced in the United States. Reflective cracking is one of the more severe issues related to the application of thin overlays. Reflective cracking is generally described as the extension of cracks from the movement of the base course or underlying pavement into and through the new overlay due to load-induced and/or temperature-induced stresses. Growing traffic loads, harsh weather, and low maintenance funding budgets exacerbate this issue and curtail the serviceable life of these pavements for numerous cities, counties, and state Department of Transportation (DOT) organizations.

With the U.S. Department of Energy estimating a 60 percent rise in world consumption of oil by 2020 from 1997 levels, the expense involved in building and maintaining these pavements will most certainly continue to rise. All these factors reduce the service life of HMA overlays and/or enhance the necessity for cost-efficient preventive maintenance methods. Some of the recent methods are the integration of geosynthetic products, which are herein defined as grids, fabrics, or composites, in the pavement structure. This process is generally achieved by bonding the geosynthetic product to the existing pavement (rigid or flexible) using an asphalt tack coat and overlaying with a certain amount of HMA pavement. These products have had varying levels of success, and their application within a specific agency has been determined largely by local experience or a desire to test a product that seems to have potential.

Definition of Geosynthetics

Geosynthetics are here defined as fabrics, grids, composites, or membranes. Geo pertains to putting the material on or in the ground or earth (e.g., in a pavement) while synthetic refers to a man-made material. The geo prefix can also be applied to fabric, grid, composite, or membrane. Grids and composites are second-generation materials created for certain applications by certain manufacturers. Fabrics or geotextiles can be woven or nonwoven and are usually made up of thermoplastics like polypropylene or polyester but can also include nylon,

other polymers, natural organic materials, or fiberglass.
Filaments in nonwoven fabrics are generally mechanically bonded (needle-punched) or adhesively bonded (spun- bonded, heat or chemicals). Paving fabrics generally range from 4 to 6 ounces/yd2 in weight. Technically, grids and composites are not geotextiles. Grids (geonets or mesh) can be woven from glass fibers or polymeric (polypropylene or polyester) filaments, or they can be cut or pressed from plastic sheets and post tensioned afterward to achieve maximum strength and modulus.
Grids usually have rectangular openings ranging from ¼ inch to 2 inches wide. A grid can be coated with a thin membrane laminated to it that helps with construction (i.e., bond to the asphalt tack coat) but melts and vanishes upon application of the hot HMA overlay. Furthermore, some grids have thin, permanent fiber strands partially occupying the apertures which bond the grid to the tack coat without creating a waterproof seal.

Fig. 1 Geosynthetics

Grids are manufactured to have high modulus at low strains in a way that their reinforcing advantages start prior to the tension failure of the protected HMA pavement layer. Composites typically form a laminate of fabric upon a grid. For the composite, the fabric offers absorbency (mainly to retain asphalt) and a sheet of continuous nature to allow sufficient adhesion of the composite on a pavement surface; while the grid offers high tensile strength and stiffness.
The third-generation products were custom designed by the manufacturers, based on field and laboratory studies, for asphalt retention and for high initial tangent modulus (i.e., high modulus under low strain levels). A heavy-duty membrane is a multi-component system, commonly a polyester or polypropylene mesh which is laminated on one side or both with an impermeable rubber- asphalt membrane. Membranes weighing around 50 to 100 ounces/yd2 are normally installed as strips on concrete pavement joints.

Implementable Products
Application-ready products of this research are a guide to employing geosynthetics with HMA overlays to mitigate reflective cracking, suggested specification revisions for employing geotextiles to mitigate reflective cracking, and a design check for the FPS-19 computer program that allows accounting for geosynthetics as an alternate to minimize reflective cracking.

2. LITERATURE REVIEW

Most HMA overlays develop a pattern of cracking prematurely identical to the cracking pattern in the existing base pavement. Cracking in the new overlay surface results from the failure of the overlay to resist shear and tensile stresses produced by movements that are localized about existing cracks in the base pavement. This movement could be due to traffic loading creating differential deflection at cracks in the base pavement layers, subgrade soils expanding or contracting, the pavement expanding or contracting because of a temperature change, or combinations thereof. Pavement movement, created by any one of the aforementioned reasons, causes shear and/or tension stresses in the new overlay.
When such stresses exceed the tensile or shear strength of the HMA, a new crack forms in the new overlay. This extension of an established cracking pattern from an old pavement into and through a new overlay is referred to as reflective cracking. Reflective cracking through HMA overlays has been a global issue for many decades. Even though reflection cracks do not typically decrease the structural capacity of a pavement, later intrusion of water and action of the natural environment and traffic can cause the premature distress and even failure of the pavement. Numerous treatments have been attempted through the years to avoid reflection cracking; none of them have been successful. While some of the treatments have proved to result in great delays in the occurrence and decreases in the number and severity of the reflective cracks, some of the new and effective products are geosynthetics. Geosynthetics used for HMA overlay reinforcement to minimize reflective cracking are the subject of this literature review.
In March 2000, Carver and Sprague (2000) concluded that asphalt reinforcement technology is relatively new, and the target pavement problem is complex. Accurate determinations of performance and economics benefits will not be made until more experience is obtained and actual performance compared to expected by currently

available design and analysis methods. Lytton (1989) noted that, whenever a load travels over a crack in the existing pavement, three pulses of high-stress concentrations develop at the crack tip, as it extends upward through the overlay. The initial stress pulse is a maximum shear stress pulse. The second pulse is a maximum bending stress pulse.

The third pulse of stress is again a shear stress pulse maximus, with the exception being in the opposing direction of the first shear pulse. Also, due to often the presence of a void behind the old surface, the maximising shearing stress when load is at C is typically bigger compared to load being at position A. These stress pulses are in a very short time, of the order of 0.05 second. At such high loading rates, the stiffness of the asphalt concrete in the overlay and in the existing pavement is very high. Every pavement movement causes a small increment in crack length in the overlay. With the increase in the number of loadings, the amount of movement increases, crack growth rate is greater, and overlay reflection cracks quickly occur at the surface of the pavement.

3. LABORATORY PROCEDURES

The intent of the laboratory study was to create data to assist in the assessment of the comparative efficiency of commercially marketed geosynthetic products to reduce the severity or postpone the occurrence of reflective cracking in bituminous overlays resulting, at least in part, from thermally induced stresses. This chapter outlines the steps followed to build and test HMA test beams containing the geosynthetic materials. All the beams were consistently manufactured utilizing a TxDOT Type D HMA supplied from a domestic manufacturing plant.

The job-mix formula (JMF) of the mix design is supplied. Six forms of geosynthetic material were purchased from suppliers of material and are described in Table 1.

Laboratory procedures generally were conducted as follows. A 1-inch HMA "level-up" mixture was compacted and cured in the mold for at least 24 hours at room temperature.

Table 1: Geosynthetic Materials Selected for Testing

Product	Manufacturer	General Description
Bitutex Composite	Synteen USA	Woven/Coated Polyester Grid/Nonwoven Composite
Pave-Dry 381	Synthetic Industries	Polypropylene Nonwoven Fabric
PetroGrid 4582	Amoco Fabrics	Woven/Coated Fiberglass Grid/Nonwoven Composite

A geosynthetic product was placed on the level-up course with AC-20 asphalt cement provided by Gulf States Asphalt Company at the rate recommended by the geosynthetic manufacturer. Once the material had set overnight and achieved complete adhesion with the level-up course, the last "overlay" course of HMA was compacted in two 1-inch lifts. The final compacted beam size was 3 inches high by 6 inches wide by 20 inches long. Six beams were geosynthetic material-reinforced, and the seventh unreinforced beam served as the "control" beam.

Three replicates for each set were constructed, making a total of 21 beams for final testing. Several other beams were constructed throughout the study to know how to create beams in a particular range of air voids, correctly tack geosynthetics, and recreate beams that had anomalous performance. TTI Overlay Tester at Texas A&M University was used to test each beam. The subsequent sections explain the materials chosen, beam fabrication methods, TTI Overlay Tester, and test procedures in more detail.

Material Selection

Researchers chose six geosynthetic products for this experiment to examine their impact on the propagation rate of cracks in a compacted bituminous mixture. There are several terminologies to explain or classify geosynthetic products. The industry broadly consists of manufacturers producing grids, fabrics, and/or composites. The researchers choose the material according to the objective of including these three kinds of products which are being currently claimed to slow down or eliminate reflective cracking in HMA overlays. The geosynthetic materials that have been chosen and tested are included in along with a general overview of the materials from which the products are constructed. These samples included two fiberglass grid composites, two polyester grid composites, a single fiberglass grid, and a single polypropylene nonwoven fabric. presents sample identifications for each of these samples along with the tack coat rates suggested by the respective manufacturers.

Table 2: Sample Identifications and Manufacturers' Recommended Tack Coat Rates

Product	Sample Identification	Recommended Tack Coat Rate (gal/yd²)	Weight of Tack Coat (grams)	Tack Coat Temperature (deg F)
Bitutex	B	0.25	87.6	300
Pave-Dry 381	PD3	0.20	70.1	300
HaTelit C40/17	HC	0.10	35.1	300

Fig -2: Uneven Coverage Using MS-1 Emulsified Asphalt Applied to Sample Beam C-20A with the HaTelit C40/17 Composite Product.

Fig -3: Lack of Complete Adhesion Using MS-1 Emulsified Asphalt Applied To Sample Beam C-3A with the Pave-Dry 381 Fabric.

Researchers conducted regular assurance tests on HMA samples from the control beams and against the JMF. The tests included bulk specific gravity, rice specific gravity, asphalt extraction, bitumen content, and dry sieve analysis. presents results of such laboratory tests. HMA mix was collected from a production plant and loaded into 40 five-gallon metal cans and closed by metal lids with rubber gaskets. The cans were numbered 1 to 40, as they were drawn for sampling, and then they were kept for further use. In each can, there was enough material to make one beam with the size of 3 inches in height by 6 inches in width by 20 inches in length. Beam identification numbers include the container number from which the sample was compacted. Beam B-5, for instance, was built with Bitutex Composite utilizing material from container number 5. Similarly, beam PD3-6 was built with Pave-Dry 381 from container number 6, and so on. A random selection method was followed in the selection of containers to build beams. describes the containers used to produce HMA specimens using various geosynthetic materials.

1. CONCLUSIONS

On the basis of the literature review, observations during the production and testing of the HMA specimens, and fracture data analysis, the following conclusions seem justified.

•Performance of geosynthetics in mitigating reflection cracking in HMA overlays has varied from extremely successful to catastrophic failures. From literature review, cost effectiveness of geosynthetics in minimizing reflection cracking typically seems to be marginal.

Much of the read publications (mostly for fabrics) was calculated in terms of cost of geosynthetics more than 10 years back. In recent past, the on-site cost of geosynthetics has proved to be conducive to paving organizations.

In general, the laboratory-tested geosynthetics always increased the number of cycles to failure in the overlay tester.

Tests of quality assurance were conducted on chosen test beams in laboratories and contrasted against the TxDOT job-mix formula (JMF). Extraction from this showed asphalt content ranging between 4.1 percent and 4.6 percent as compared to the ideal asphalt content of 5 percent. The use of insufficient asphalt cement yields substandard film thickness around aggregate particles and lowers the tensile strength of the mixture. This mix for this research was collected as a sample from a production plant and was stored in metal cans.

6. REFERENCES

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