INTERNATIONAL SOCIETY FOR SOIL MECHANICS AND GEOTECHNICAL ENGINEERING

This paper was downloaded from the Online Library of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). The library is available here:

https://www.issmge.org/publications/online-library

This is an open-access database that archives thousands of papers published under the Auspices of the ISSMGE and maintained by the Innovation and Development Committee of ISSMGE.

Wicking Fabric Interactions with Different Soil Types

C. Lin & X. Zhang
Department of Civil, Architectural and Environmental Engineering, Missouri University of Science and Technology, Missouri, USA

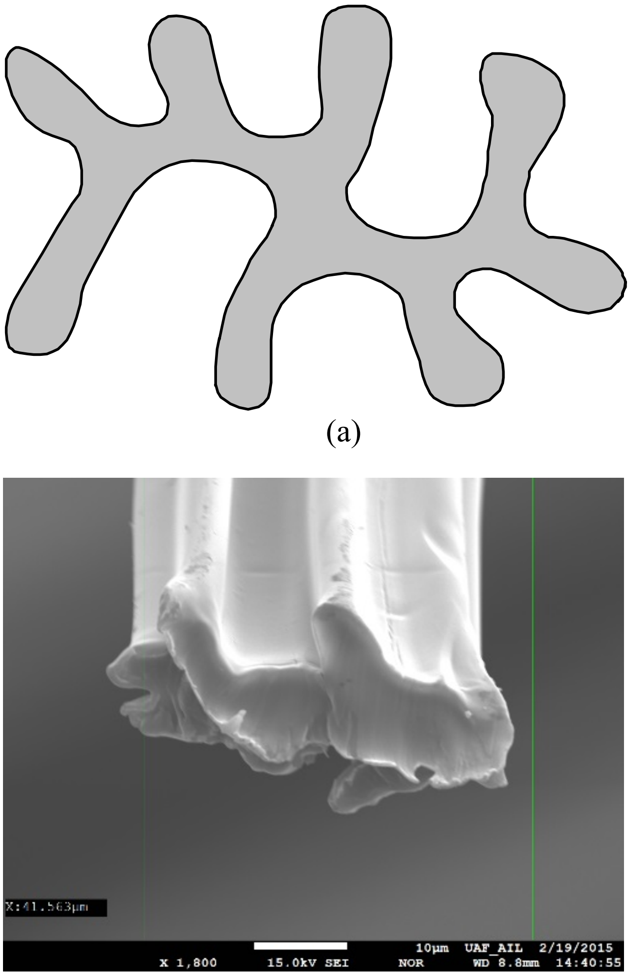
ABSTRACT: Water is one of the major detrimental factors that reduces pavement service life. A pavement section with a moderate stability factor will be serviceable only about 50% of its fully drained performance period. The problem will worsen with time because cracks become wider, joints and edges become more deteriorated. However, the existing subsurface drainage design methods only considers water flowing under gravitational force and capillary water is considered undrainable. No matter how well the road is compacted, it will gradually suffer from moisture increasing for the long run. Fortunately, a recently developed geotextile with wicking fabrics has the potential to dehydrate the base course under unsaturated conditions. Both lab and field tests have proved its efficiency in laterally draining capillary water under unsaturated conditions. The purpose of this paper is to evaluate the geotextile drainage efficiency when applied with different types of soils. Two types of soils were used to simulate good and bad drainage conditions. Test results indicated the geotextile with wicking fabrics is effective and capable to drain capillary water out of the soils.

1 INTRODUCTION

Excess water can cause numbers of detrimental issues, for instance, causing soil expansion and collapsing, reducing the soil strength and stiffness, increasing excess pore water pressure and developing seepage forces, stripping asphalt pavement and generating cracks (Arnold 2004). For unbounded aggregate base and subbase, the stiffness loss is about 50% or more. The resilient modulus loss for ATB (Asphalt Treated Base) layer can be up to 30% and this value is over 50% for fined-grained soils (AASHTO 1993). Moreover, the excess water induced problems will be worsen with time. Cracks will become wider, joints and edges become more deteriorated, and channels will be developed for water flow. If the pavement system is saturated only 10% of its life (about a month per year), a pavement section with a moderate stability factor will be servable only about 50% of its fully drained performance period (Cedergren 1987). Furthermore, when encountered with shallow groundwater table and subfreezing temperature, frost heave and subsequent thaw weakening will cause severe distresses (Henry 1990).

By investigating the existing subsurface drainage design methods (AASHTO 1993, FHWA 1980, and MEPDG 2004), traditional approaches to address moisture in pavements involve implementing a layer of either geotextile or coarse material, which has large pore size that allows water to freely flow out of the pavement meanwhile stops capillary water from rising upward. However, conventional drainage systems were designed for water flow driven by gravity (free water), and capillary water was not considered in the designing process. Recently, a new type of geotextile with wicking fabric has been developed, which is designed to drain capillary water under unsaturated conditions. The cross section of the fibre has special multi-channels that can provide high surface areas and channels to wick water under unsaturated conditions (see Figure 1). The average diameter of the wicking fabric is between 30-50 μm and the average groove spacing is between 5-12 μm. Both lab and field tests proved its efficiency in dewatering road embankment and capability of wicking capillary water out of soils (Zhang and Presler 2012, and Zhang et al. 2016).

There are still some concerns regarding the extensive application of the geotextile. Firstly, will the geotextile be still functional with different types of soils. Secondly, will the geotextile splicing influence its drainage efficiency. The purpose of this paper is to evaluate the effectiveness of the geotextile with wicking fabric when applied with different types of


(a)

(b)

Figure 1. Cross section of the wicking fabric. (a) schematic plot; and (b) SEM image of cross section

soils. Two types of soils were used to simulate good and bad drainage conditions. Detailed information is demonstrated in the following sections.

2 TESTING FLUME CONSTRUCTION

Two types of materials were used to evaluate the new geotextile drainage efficiency, including a free-draining, clean river sand, and a gravel with silt (designated as E-1 material per AKDOT specification), a dense graded soil with about 14% fines. The gradation curves are shown in Figure 2. The sand material is used to provide an understanding of how well the new geotextile works in permeable soil. For E-1 material, this type of soil contains about 14% of fines and is the commonly used in the unpaved road as a surface course. Soils containing more than 6% of fines are classified as frost susceptible soils. Therefore, this type of soil can be a representative to demonstrate the geotextile drainage efficiency in similar frost susceptible soils. In addition, the numbers of the geotextile splice sections may increase for wider road sections and the drawbacks of the application for this type of road is also evaluated in this paper.

Two testing flumes were constructed to evaluate the soil-geotextile systems drainage efficiency. One testing flume was 6.5 m (width of a two-lane road) in length filled with sand, and the other one was 22.3 m in length filled with E-1. Here only take the testing flume for sand as an example to demonstrate the construction process due to the similarity in flume design. Figure 3a shows the schematic plot of the design. The testing flume was covered with a layer of plastic wrap to prevent water leaking. The geotextile was installed 2.54 cm from the bottom. A 1-m geotextile splice was placed at 1.52 m from the left side due to the limited geotextile roll width (5.18 m). Then the soil and geotextile were saturated, and EC-5 moisture sensors were installed (see Figure 3b). In total, three layers of sensors were installed at depths of 2.54 cm, 12.7 cm and 22.86 cm. The testing flume was oversaturated before the test started. The data acquisition system composed of a CR1000 data logger and a AM16/32 multiplexer. The moisture content data was recorded hourly.

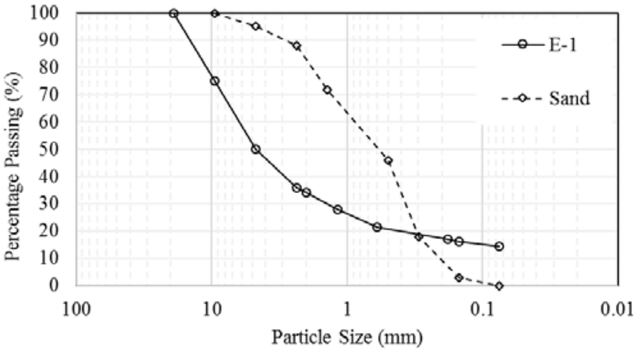
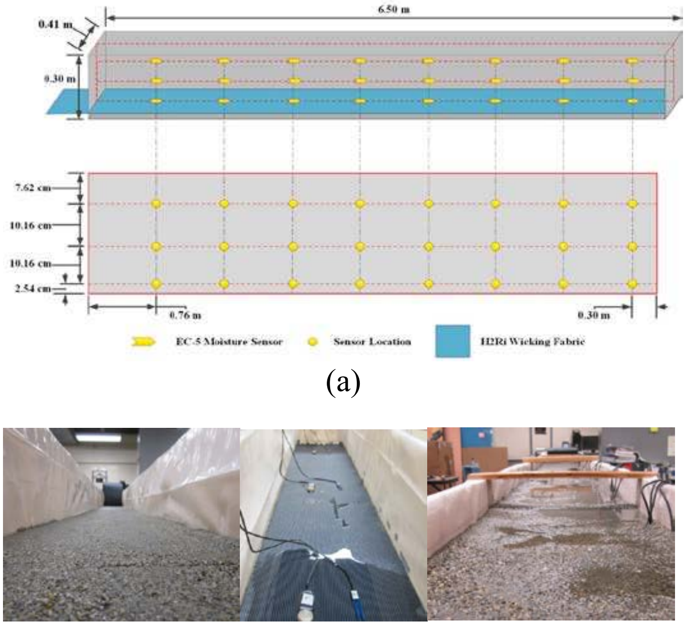


Figure 2. Gradation curves for sand and E-1 materials.



(a)

(b)

Figure 3. Testing flume construction process. (a) schematic plot of testing flume for sand; and (b) construction process

3 TEST RESULTS

The recorded data was first used as controlling points to generate moisture contours. Due to limited numbers of sensors, one dimensional interpolation was adopted to achieve the best visualization of the moisture variations within the testing flume. Figure 4a shows the test results for sand. The dash line represents the geotextile location and the colormap ranges from white (lowest moisture content, 0.1) to black (highest moisture content, 0.35). The saturation moisture content for sand was 0.3, which could be used as an indication of any saturated zone in the testing flume. The average moisture content on the left side was about 0.23 and 0.28 on the right side. In addition, a zone (0.29 isoline) extended from 1.8 m to 3.6 m in the horizontal direction, where was the geotextile splice location. The test was conducted for one month. After the test, the moisture content on top of the testing flume was 0.16, which was 32.3% smaller than that at the beginning of the test. The area of the saturation zone at 3 m increased while the saturation zone at 5.5 m was replaced by a drier area than the surrounding soil. In addition, the moisture content from 1 m to 2 m continued to decrease, resulting in an expansion of the dry zone in the left section. In sum, these observations verified the fact that the geotextile had the ability to wick capillary water out of the testing flume. However, the geotextile splice impeded the wicking process and significantly reduced its drainage efficiency.

Figure 4b shows the test results for E-1 material. The saturation moisture content was 0.4. At the starting point, the moisture content at elevation above 0.12 m was between 0.12 and 0.15. There were several spots with moisture content close to 0.2, which might result from soil inconsistency and less compaction effort. For elevation lower than 0.12 m, in total six water concentration (saturated or nearly saturated) zones were all observed at the geotextile splice locations. The saturation zones were at three locations (5.3 m 14.0 m and 17.0 m). After the test, the remaining oversaturation were all located at the geotextile splices. Moreover, a minimum of 0.3 m of the geotextile exposed to the air remained in wet condition after the test, indicating that it continued to work.

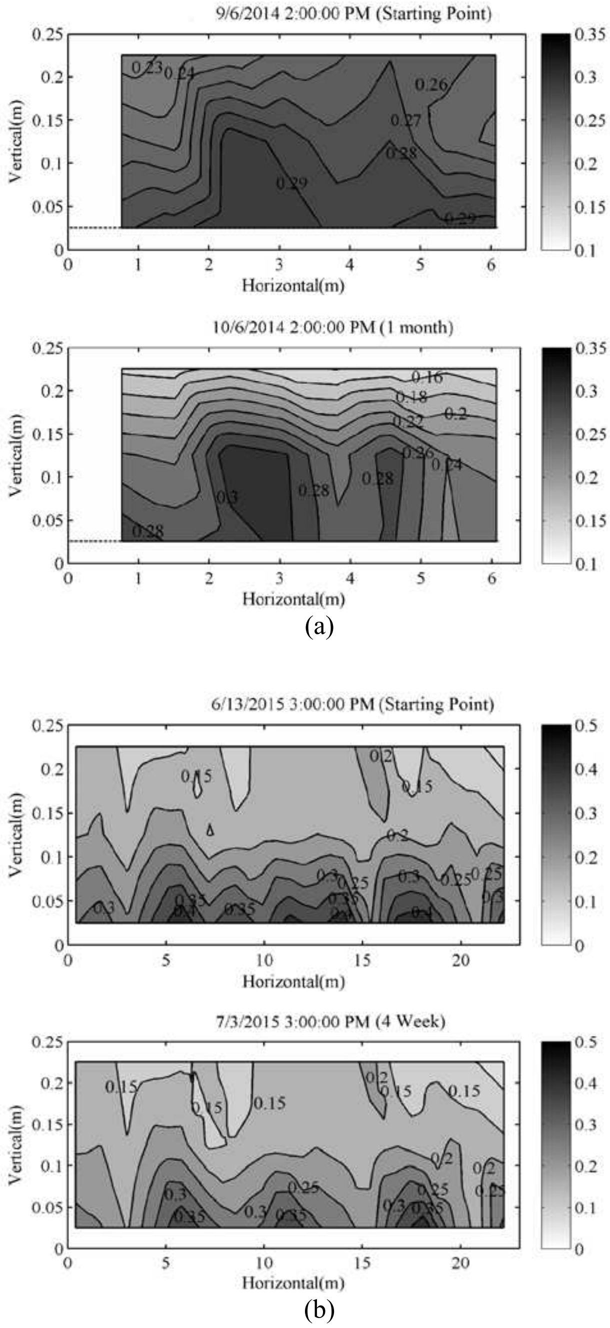


Figure 4. Moisture contours before and after test. (a) testing flume for sand; and (b) testing flume for E-1

4 CONCLUSIONS

This paper studied the drainage efficiency of a new geotextile when contacting different types of soils under unsaturated conditions. The new geotextile had the ability to wicking capillary water by taking advantage of the suction gradient generated between the two ends.

The new geotextile still functioned after the test for both sand and E-1 materials. It is a continuous process and can reduce the soil moisture content to a lower level for the long run. However, geotextile splices significantly reduced the drainage efficiency, resulting in excess water accumulation. For future work, the influence of splice on the new geotextile drainage efficiency needs to be further investigated.

5 REFERENCES

Arnold, G.K. 2004. *Rutting of granular pavements*. PhD Thesis, University of Nottingham, UK.

American Association of State Highway, & Transportation Officials (AAAHRO). 1993. *AASHTO Guide for Design of Pavement Structures*. Vol. 1.

Cedergren, H.R. 1987. *Drainage of Highway and Airfield Pavements, Second Edition*. Robert E. Krieger Publishing Company, Inc., Malabar, FL.

Henry, K.S. 1990. *A case study of potential causes of frost heave*. No. CRREL-SR-90-9, Cold Regions Research and Engineering Lab, Hanover NH.

FHWA (Federal Highway Administration). 1980. *Highway Subdrainage Design. Publication*. Federal Highway Administration (FHWA), FHWA-TS-80-224, U.S. Department of Transportation.

NCHRP (National Cooperative Highway Research Program). 2004. *Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*. National Cooperative Highway Research Program, NCHRP Project 1-37A Report, National Research Council. Washington, DC.

Zhang, X. & Presler, W. 2012. *Use of H2Ri Wicking Fabric to Prevent Frost Boils in the Dalton Highway Beaver Slide Area, Alaska*. Alaska University Transportation Center (AUTC), Project Report, No. RR10.02 & 510020, August 2012.

Zhang, X., Presler, W., Li, L., Jones, D. & Odgers, B. 2014. Use of Wicking Fabric to Help Prevent Frost Boils in Alaskan Pavements. *Journal of Materials in Civil Engineering*, ASCE 26(4): 728-740.