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Technical note

# Reduction of subgrade fines migration into subbase of flexible pavement using geotextile

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ABSTRACT

Pumping in pavement is defined as traffic-induced migration of saturated subgrade fines into overlying granular layers or onto the surface of the pavement, negatively impacting the performance and service life of the pavement. The objective of this study was to assess the capability of geotextile as a separation and filtration layer in reducing subgrade fines migration. A one-third scale Model Mobile Load Simulator, an accelerated pavement testing device, was used to simulate the cyclic traffic loading on a scaled model of a flexible pavement. The results from three scaled pavement tests were compared to evaluate the effectiveness of geotextile separation and filtration in reducing subgrade fines migration. The three tests had identical configurations, except that a geotextile layer was placed at the interface of subgrade and subbase in one of the tests. The lab testing revealed that, under cyclic traffic conditions, the migration of subgrade fines into subbase was significant. However, using a geotextile at the subgrade-subbase interface significantly reduced the subgrade pumping. At the end of the test, the fines that migrated to the subbase, based on % mass of subbase, were 6.39% in the tests without geotextile and 1.81% in the test with geotextile. An approximately 30% reduction was observed in the amount of pavement rutting when using geotextile at the top of the subgrade. The subgrade soil migration in mass percentage increased with the traffic loading cycles, and more migration occurred in the bottom half than in the top half of the subbase. The study concludes that geotextile can be used as an effective means to reduce pumping of subgrade fines in pavement by providing both separation and filtration.

## 1. Introduction

In order to properly design and rehabilitate pavement structures, it is essential to understand possible failure mechanisms that may occur over their service lives. Pumping of subgrade fines is among the common undesirable mechanisms in pavement systems (Christopher et al., 2006). Pumping is defined as the intrusion of subgrade fines from a fully saturated fine-graded subgrade soil into the overlying granular layers of pavements under cyclic traffic loads (Alobaidi and Hoare, 1994). This phenomenon has been attributed largely to the development of excess pore water pressure at the subgrade-subbase interface due to cyclic traffic loading (Alobaidi and Hoare, 1996, 1999). Only a few experimental studies have been conducted to investigate the mixing of subgrade soil with the overlying coarse aggregate due to upward migration of the subgrade material (Alobaidi and Hoare, 1994, 1996, 1998a; Henry et al., 2013; Kermani et al., 2017; Trani and Indraratna, 2010). Due to pumping and the resulting gradual clogging of granular layers of pavement, the drainage capacity and stability of pavements are reduced, which in turn may cause failure (Holtz et al., 2008).

Separator layers play a vital role in the performance of a pavement by preventing subgrade fines from infiltrating into the overlying permeable subbase, thus maintaining the permeability of this layer (Al-Qadi and Appea, 2003; Al-Qadi et al., 1994; Christopher et al., 2006). A separator layer may decrease rut formation and reduce the required thickness of granular layers, which has both economic and ecological advantages (Hufenus et al., 2006). In pavement design, increasing the thickness of subbase and using material such as sand between subgrade and subbase have been found effective in controlling the pumping of fines, with varying degrees of success and cost (Ayres, 1986; Guram et al., 1994; Snaith and Bell, 1978). As an alternative to granular filter layers, a properly selected geotextile may be a more effective and economical means of separation and filtration, due to its excellent hydraulic properties such as high apparent opening size and clog resistance. Ingle and Bhosale (2017) and Marienfeld (2013) indicated that using geotextile in pavements may extend their service lives. While several studies have been conducted on the application of geotextiles to control pumping, those studies primarily focused on the separation behavior of the geotextile (Alobaidi and Hoare, 1998b; Bell et al., 1981;

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Black and Holtz, 1999; Collins et al., 2005; DeBerardino and Baldwin, 1996; Leu and Tasa, 2001; Metcalfe et al., 1995; US. Army Corps of Engineers, 1999). At the time of their paper, Alobaidi and Hoare (1994) indicated that little effort had been made to investigate the preventive capability of geotextile against pumping as a result of filtration. Koerner and Koerner (2015) discussed several case histories of clogging of inappropriately selected geotextile in contact with fine-grained soils. Brorsson and Eriksson (1986) surmised that a certain type of geotextile, which was not available at the time of their study, might be effective in controlling subgrade fines migration under intensive cyclic loading.

In this study, a one-third-scale model mobile load simulator (MMLS3), a reduced scale accelerated pavement testing (APT), was used. The MMLS3 has four tires that sequentially apply traffic loading on a pavement. The tires are smaller than the tires for full-scale loading (Bhattacharjee et al., 2004; Hugo, 2000). The MMLS3 applies scaled loading, such that if the thicknesses of the pavement layers are approximately one-third of the actual thicknesses of in-situ pavement layers, approximately equivalent mechanical responses are produced (Epps Martin et al., 2003). The current study reports the results of a set of laboratory tests conducted using the MMLS3 to evaluate the effect of geotextile in preventing pavement pumping. The research objectives were achieved by comparing the results of pumping of subgrade soil into the subbase layer for two cases: (a) Test 1 simulated the cyclic traffic loads on flexible pavement representing collector roadway. A replicate test (Test 2) was performed to verify the repeatability of the results. Details of the test equipment, method, results, and analysis are provided in Kermani et al. (2017). (b) Test 3 was identical to Tests 1 and 2 except that a layer of geotextile was placed at the subgrade-subbase interface of the scaled pavement to evaluate the effectiveness of this separator layer in preventing subgrade fines migration (pumping). In this paper, the results of Test 3 are first presented, followed by a comparison between the results obtained from Test 3 (with geotextile) and Tests 1 and 2 (without geotextile).

## 2. Materials and methods

### 2.1. Materials

A comprehensive description of the materials (except for geotextile) was reported in Kermani et al. (2017). The grain size distributions (GSDs) of subgrade soil and aggregate subbase are shown in Fig. 1. A nonwoven, needle-punched geotextile made of 100% polypropylene staple fibers was chosen for the filter and separation layer. Polypropylene geotextiles can resist ultraviolet (UV) deterioration, rotting, biological degradation, and naturally-encountered bases and acids. Polypropylene is stable within a pH range of 2–13 (SKAPS Industries, 2017). The physical properties of the geotextile are presented in Table 1.

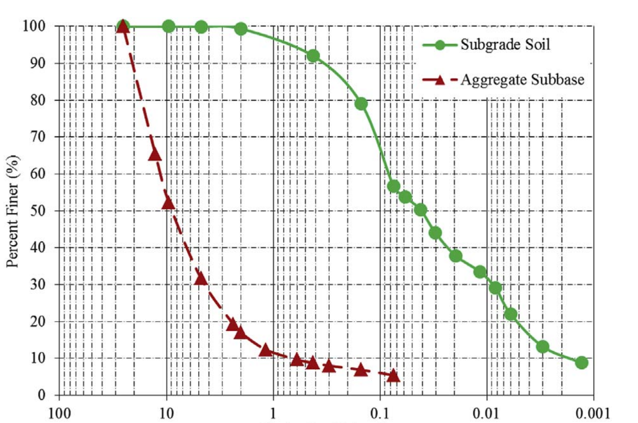


**Fig. 1.** Grain size distributions of subgrade soil and aggregate subbase used in the tests.

The ability of a geotextile to retain fines primarily depends on its opening size. Narejo (2003) performed laboratory and field tests to study the retention behavior of geotextiles under dynamic conditions. The geotextile's openings should be large enough to allow unimpeded seepage and small enough to minimize fines migration through the geotextile. The apparent opening size (AOS) was evaluated to ensure it met the required filtration criteria for nonwoven geotextiles on non-cohesive silty soil (Christopher et al., 2006; Koerner, 2012; Narejo, 2003):

$$AOS \leq D_{85} \quad (1)$$

$$AOS < \frac{18}{c_u} D_{50} \quad (2)$$

where $D_{85}$ is the soil particle size in mm for which 85% of the soil is finer, $D_{50}$ is the soil particle size in mm for which 50% of the soil is finer, and $C_u$ is the coefficient of uniformity of the subgrade soil. The AOS of the geotextile was 0.15 mm; therefore, based on the GSD of the subgrade in Fig. 1, the geotextile met the filtration criteria.

### 2.2. Methodology

In this study, a scaled structural section representing a typical flexible pavement for a collector road was constructed and tested using the MMLS3. Analyses were conducted to determine equivalent section thicknesses in the lab such that the vertical stress at the interface of subgrade and subbase directly underneath the wheel path of the MMLS3 was similar to the corresponding stress in the modeled full-scale pavement section, as detailed by Kermani et al. (2017). The thicknesses of subgrade, subbase, and asphalt concrete for the scaled pavement were determined to be 91.4 cm, 10.2 cm, and 3.8 cm, respectively. With similar stresses at the subgrade-subbase interface in the scaled pavement and the field condition, the excess pore water pressure generation and the resulting fines migration observed in the lab quantitatively represent the field performance under saturated conditions. Material properties, including gradation of the aggregate subbase and subgrade, were not scaled. The presence of geotextile was not considered in the layer thickness analysis. The scaled pavements were constructed in a rigid, reinforced steel container in an underground pit.

To measure stresses in the scaled models for comparison to full-scale conditions, two earth pressure cells (E1 and E2) were placed at the subgrade-subbase interface. Semiconductor strain gage piezometers from Geokon, with 0–5 VDC output and 100 kPa measurement range, were utilized. The earth pressure cells were also from Geokon, with 10.16 cm diameter and 250 kPa measurement range. The pressure cells were installed under the wheel path to measure vertical total stress. Seven piezometers (P1-P7) were embedded at different elevations of the model—one at the bottom of subgrade, four at 1.27 cm down into the subgrade, and two at 1.27 cm up into the subbase—to capture generation of dynamic pore water pressure in the model due to induced traffic loads. Piezometers were also used to monitor the saturation process of the model. Detailed information of the instrumentation configuration and data acquisition is presented in Kermani et al. (2017).

A cross-section of the scaled pavement for Test 3 with geotextile is presented in Fig. 2. The cross-sections of the scaled pavements for Tests 1 and 2 were the same as in Test 3, with the absence of the upper geotextile layer. In Test 3, after the subgrade was constructed, the geotextile was carefully placed on top of the subgrade, separating the subgrade and subbase. The edges of the geotextile were securely taped to the sidewalls of the steel container to restrict possible movement of the geotextile and to simulate its restraint by the surrounding pavement in the field. The model pavement was then saturated. The degree of saturation was determined to be approximately 98.5% for all three tests. The MMLS3 was used to apply cyclic traffic loading to the scaled pavement, with a wheel load of 2.7 kN and contact pressure of 700 kPa.

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