Performance of Geotextile Separators in Laboratory Model Tests

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ABSTRACT: This paper describes on-going laboratory model tests to investigate geotextile performance under conditions that simulate loading conditions in roadways. The performance of different geotextiles used for stabilization of soft subgrade soils, as well as their long-term performance in the pavement system, are being evaluated. The test results are presented, and the survivability and filtration performance of the geotextiles is evaluated and compared.

1 INTRODUCTION

When a highway is constructed over a soft subgrade, failure most commonly occurs when the base and/or subbase aggregate becomes intermixed with the subgrade soil. A geotextile can be placed between the aggregate and the subgrade to act as a separator to prevent the subgrade and aggregate base course from mixing. As such, the primary function of the geotextile in roadway applications is separation. The system may also be influenced by secondary functions of the geotextile including filtration, drainage, and reinforcement.

In order to clarify some uncertainties in field performance of geotextiles in roadways, an experimental study was conducted to investigate their performance under controlled conditions. The work consisted of a series of laboratory model tests in an apparatus that simulated roadway loading conditions. The performance of different geotextiles under two different base layer thicknesses and after various cycles of load applications was monitored.

2 EXPERIMENT SETUP AND TEST PROCEDURES

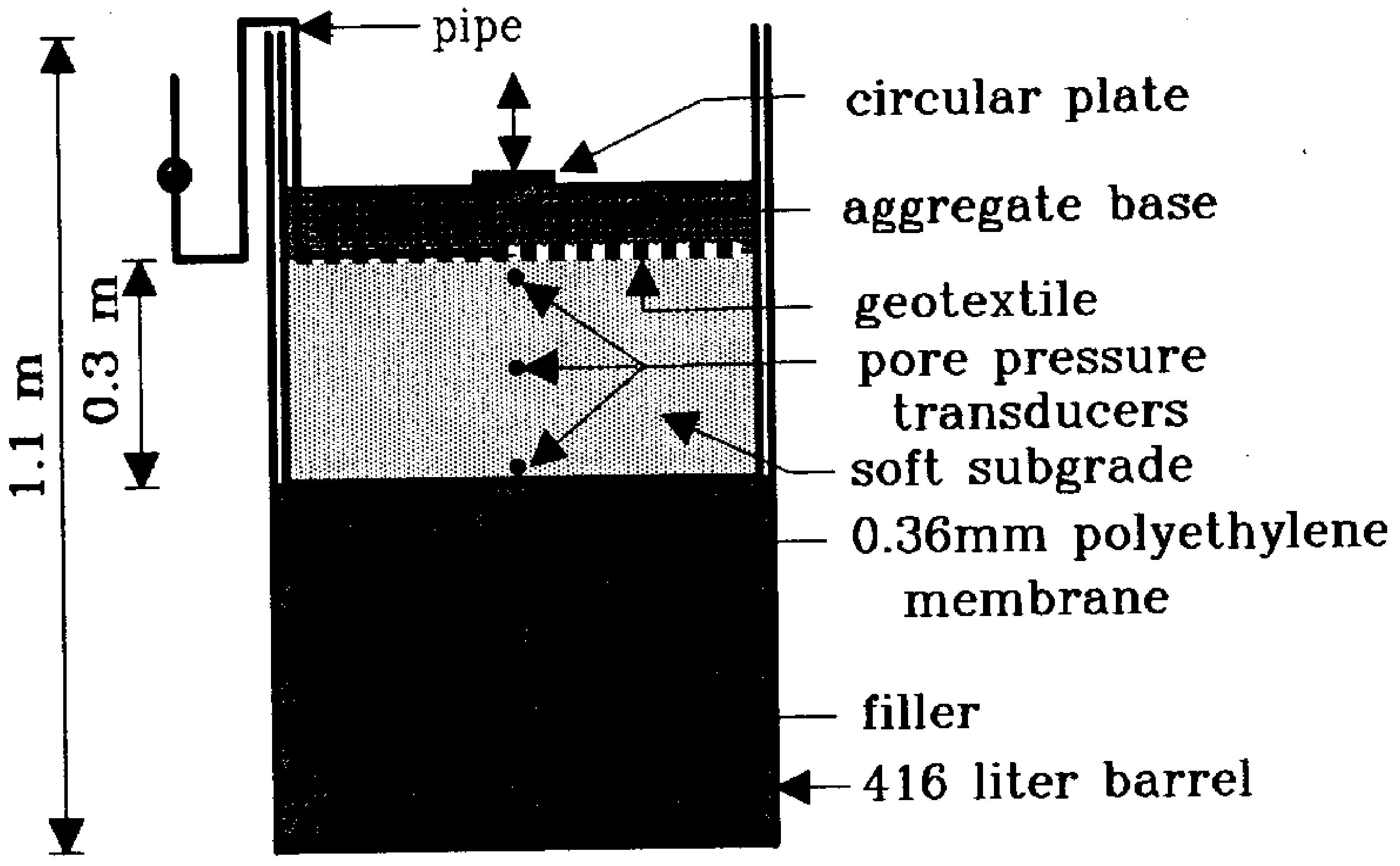

Fig. 1 Experiment setup.

Geotextiles were placed on a soft saturated subgrade, as shown in Fig. 1, and covered with a layer of compacted crushed stone aggregate. To simulate a standard 40 kN single wheel load on a typical vehicle tire, a circular steel plate was utilized to apply a 4.9 kN load at a frequency of 1 Hz. To evaluate the ability of geotextiles to dissipate excess pore pressures induced in the soft subgrade soils, pore pressure transducers buried within subgrade monitored changes in pore pressures during loading. In addition, fine particles migrating from the soft subgrade soils were also observed to evaluate the ability of the various geotextiles to retard base course contamination.

Testing procedures were as follows:

1. Place water into the steel drum and then deposit soil into the water. Apply step loading on a large steel plate to reach the consolidation stress required to obtain a subgrade with a certain CBR.
2. Perform a CBR test on the subgrade and take soil samples for water content determination.

3. Place a geotextile on the top of the subgrade and anchor it along its periphery by a steel hoop.
4. Place aggregate on the geotextile to the design thickness and compact it to the design density.
5. Apply repeated load to the aggregate; record the displacement of the surface and the pore pressures within the subgrade.
6. Remove the overlying aggregates and inspect the geotextile.
7. Recover the geotextile and measure its residual physical and mechanical properties.

3 TEST PARAMETERS AND GEOTEXTILE PROPERTIES

Five laboratory model tests have been conducted to date. Table 1 shows the parameters of these five tests. Separator geotextiles included a 140 g/m^2 heatbonded nonwoven and a 140 g/m^2 needlepunched nonwoven. Table 2 shows some of the nominal properties of the geotextiles employed in the study. As a control, one test was conducted with a properly designed (U.S.B.R. 1974) graded granular filter (25 mm thick) as a separator. Another test used an impervious 0.36 mm polyethylene membrane protected by a 530 g/m^2 needlepunched nonwoven geotextile. Two different base course thicknesses, 40 and 110 mm, were used in the tests to model two different thicknesses of real base courses (100 and 300 mm, respectively). Therefore, in the model tests, geotextiles under a 4.9 kN load experienced same vertical stress as under a standard 40 kN wheel load. In terms of filtration, the granular filter and the impervious membrane were considered to be two extreme conditions for modeling subgrade separators. The granular filter separator should be the best filter. On the other hand, the impervious membrane could simulate a condition where the geotextile was clogged completely.

Table 1 Test parameters.

Test No.	Thickness of Aggregate Course (mm)	Separator
40-HB4	40	HB4*
40-NP4	40	NP4**
110-NP4	110	NP4**
110-GF	110	Granular Filter
110-MEM	110	Membrane

*HB4 = 136 g/m^2 heatbonded nonwoven geotextile.
**NP4 = 136 g/m^2 needlepunched nonwoven geotextile.

Table 2 Geotextiles used.

	HB4	NP4
Type	Heatbonded	Needlepunched
Mass/Area (g/m^2)	136	136
Grab Strength (kN)	0.6	0.5
Elongation (%)	60	50
Survivability Level*	Medium	Medium

*based on Task Force 25 (1989).

4 RESULTS AND DISCUSSION

The tests were conducted following the test procedures described in Section 2, except the tests with thin base courses (40-HB4 and 40-NP4). In these two tests, the base course was removed and backfilled after ten cycles to observe the condition of the geotextiles, because the geotextiles were believed to have failed according to Task Force 25 (1989).

In the 40-HB4 test, the geotextile was found to have failed, when the test was stopped after 50,000 cycles. HB4 has 60% elongation at failure in grab tensile test and has a tensile strength of 0.6 kN; based on Task Force 25 (1989), HB4 has a lower marginal “Medium” survivability level. However, the loading condition had a “Medium” to “High” construction survivability rating based on Task Force 25 (1989) ratings. Hence, it is not surprising to find that HB4 ultimately failed. Fig. 2 shows the development with time of rut depth and pore pressures in the subgrade. From Fig. 2, it can be seen that HB4 appeared to fail about 15,000 cycles, because there was an abrupt increase in rut depth of the aggregate surface as well as in pore pressures generated. At this point, the maximum pore pressure occurred in the middle of the subgrade. After HB4 was removed, it was found to have a large hole about the size of the loading plate.

After 50,000 cycles of repeated load in the 40-NP4 test, the geotextile was recovered and inspected. Some small holes were found; the largest hole had a diameter of 6 mm. Most holes were located directly below the loading area. NP4 has 50% elongation at failure in grab tensile tests and its tensile strength is 0.5 kN, so NP4 has a lower marginal “Medium” survivability level according to Task Force 25 (1989). Since the loading condition had a “Medium” to “High” construction survivability rating, it is surprising that NP4 survived as well as it did. The survival of NP4 under this loading condition implies that the mechanical property requirements recommended by Task Force 25 (1989) may be conservative for needlepunched geotextiles.

This observation was also confirmed by the 110-NP4 test. In this test, the loading condition had a “Medium”

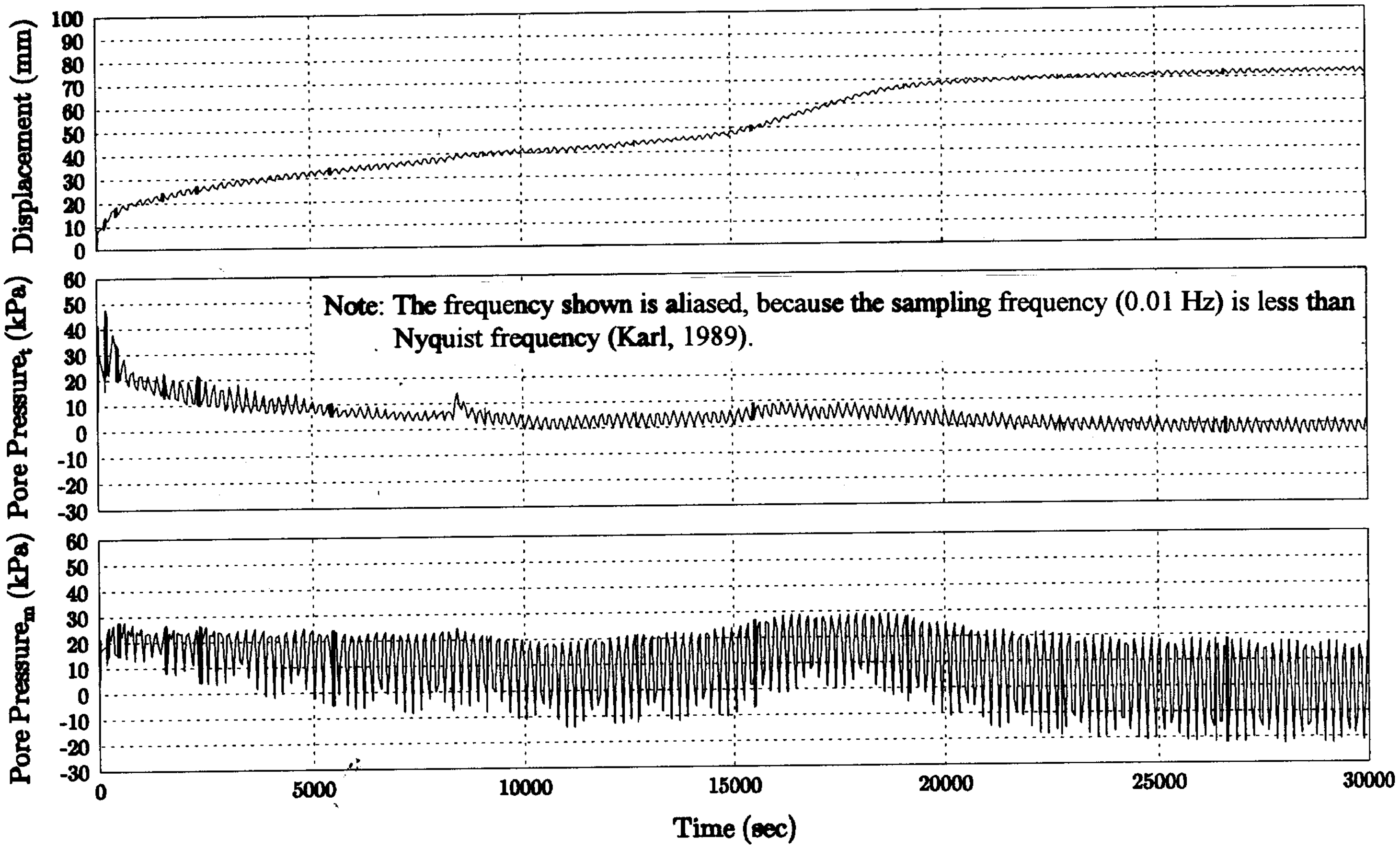

Fig. 2 The rut depth and pore pressures developed with time in Test 40-HB4.

survivability rating, which is same as the survivability level of NP4. After an arbitrary cut-off of 38,500 cycles, the geotextile was removed and inspected. Some small holes were found in the geotextile; the largest hole had a diameter of 10 mm. Most holes were located directly below the loading area.

After 67,600 cycles of repeated load in the 110-GF test, the base course aggregate was removed. Only minimal thickness of granular filter separator, which was 25 mm thick before test, was retained after the dynamic loading. The displacement of the granular filter reduced the effective thickness of the base course and correspondingly increased the stress level on the subgrade surface. Therefore, the easy displacement characteristics of the granular filter separator material (sand) resulted in deep ruts on the aggregate surface as well as on the subgrade surface.

After 82,300 cycles in the 110-MEM test, the subgrade surface had a shiny appearance after the plastic sheet was removed. It appeared that water had exited from the subgrade and accumulated underneath the membrane.

In addition to the rut depth of the aggregate surface, Fig. 2 also shows the pore pressures induced within the subgrade at two different depths, referred as *top* and *middle* in the 40-HB4 test. The results of the other four tests also show similar behavior except that they do not have any jump in the curves such as occurred in this test at 15,000 cycles. Due to lack of space, curves from the other four tests are not shown in this paper.

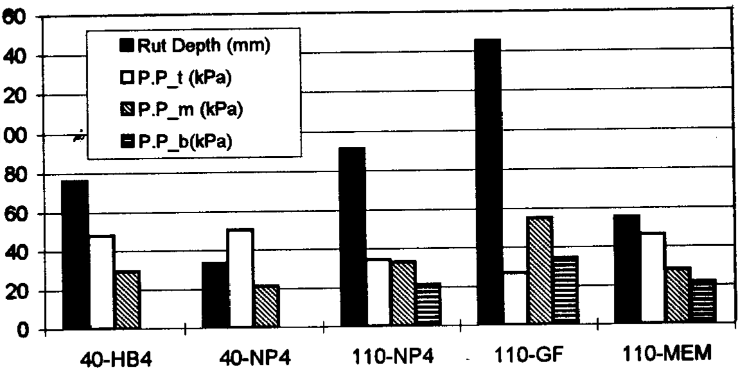

Fig. 3 Final and peak pore pressures of the tests.

Fig. 3 illustrates the final rut depths of the aggregate surface and the peak pore pressures developed in the subgrades of all five tests. In all tests, the pore pressure at the top of subgrade dissipated the fastest. This is reasonable, since the drainage path is shortest at this location. In these five tests, pore pressures accumulated with time initially and then decreased after about 500 cycles. This means that the most critical condition occurs at about 500 cycles, except for test 40-NP4. In this test, the highest excess pore water pressure occurred at 80 cycles.

Results also show that different geotextiles with different tensile moduli have different rut depths of the base course surface. This verifies that the reinforcing effect is influenced by the tensile modulus of the separator (Giroud and Noiray, 1981; Holtz and Sivakugan, 1987). The tests with a 40 mm thick base course have shallower ruts on the base course surface than those with a 110 mm thick base course. This is because that the aggregate in the tests with thinner base courses were removed and backfilled after the first ten cycles. This process was not performed in the tests with thicker base courses because the geotextiles are believed to have survived in those tests. The subgrade had, to certain extent, plastic deformation and the geotextiles were stressed before the second stage (i.e. long-term dynamic loading). Hence, prestressing or prerutting might increase the reinforcing effect (Haliburton, et al., 1980).

Between the two tests with a 40 mm thick aggregate layer, test 40-HB4 had a greater rut than test 40-NP4 (Fig. 3). It is because that test 40-HB4 lost the reinforcing effect due to the tearing of the geotextile. Both tests had similar peak pore pressures in the top of the subgrade. In the middle of the subgrade, test 40-HB4 had slightly higher pore pressure than test 40-NP4.

Among the tests with a 110 mm thick base course, test 110-MEM had the highest modulus, so this test had the least depression on the surface of base course (55 mm). On the other hand, because the separator of the 110-GF test did not have any tensile strength, this test had the deepest rut depth (145 mm). Therefore, different reinforcing effects apparently are obtained from different separators. Results also show that the 110-GF test needed the shortest period of time to reach a stable state.

Among the tests with a 110 mm thick aggregate layer, test 110-MEM had the highest peak pore pressure, 46 kPa , in the top of the subgrade (Fig. 3). Test 110-GF had the lowest peak pores pressures, 28 kPa, in the top of the subgrade. In the middle of the subgrade, the 110-GF had the highest pore pressures, 55 kPa; the 110-NP4 test had a higher pore pressure than the 110-MEM test. In the bottom of the subgrade, the 110-GF test also had the highest pore pressures, 34 kPa; the other two tests (110-MEM and 110-NP4) had similar pore pressures in the bottom of the subgrade, about 21 kPa. The reduction in the thickness of aggregate layer caused by the easy displacement of granular filter results in an increase in the vertical stress on the subgrade. The pore pressure cannot dissipate easily in the middle and bottom of the subgrade; therefore, test 110-GF had the highest pore pressure in the middle as well as the bottom of the subgrade.

Based on the observation of the removed crushed stone, it was found that the amount of fine particles which migrated up through HB4, NP4 and the granular filter was minimal and negligible.

5 SUMMARY AND CONCLUSIONS

Based on the results from the five laboratory model tests, we find that Task Force 25 criteria and recommendations can be applied to HB4 with respect to survivability but may be conservative for NP4. NP4 and the granular filter performed equally well as separators in terms of their filtration function. All separators have good performance in retarding fines migration, if they survive the dynamic loading. Because the granular filter was easily displaced, it had a significant reduction in effective base course thickness; and thus a large stress level on subgrade surface resulted. Hence, NP4 had a better overall performance than the granular filter. The use of separators with different moduli can cause different final rut depths and result in different periods of time to dissipate pore pressure.

6 ACKNOWLEDGMENTS

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REFERENCES

Giroud, J.-P., and Noiray, L. (1981). Geotextile-Reinforced Unpaved Road Design, *Journal of the Geotechnical Engineering Division, ASCE*, Vol. 107, No. GT9, pp. 1233--1254.

Haliburton, T. A., Lawmaster, J. D., and King, J. K. (1980) Potential Use of Geotechnical Fabric in Airfield Runway Design, Report to US Air Force Office of Scientific Research, Oklahoma State University, Stillwater, 121 pp.

Holtz, R. D., and Sivakugan, N. (1987). Design Charts for Road with Geotextiles, *Geotextiles and Geomembranes*, Vol. 5, pp. 191--199.

Task Force 25 (1989) Guide Specification for Geotextiles in Separation Applications, AASHTO-AGC-ARBTA Joint Committee.

U.S. Bureau of Reclamation (1974) *Earth Manual*, 2nd Ed., Denver, 810 pp.

Karl, J. H. (1989), *An Introduction to Digital Signal Processing*, Academic Press, Inc., San Diego, 341 pp.