Laboratory Filtration Performance of Nonwoven Geotextiles

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ABSTRACT: Geotextiles are now commonly used for filtration and engineers are concerned with the compatibility of designed soil/geotextile system. Many filtration design criteria have been produced by various researchers, but none has been accepted as the universal design criteria. Hence, laboratory tests are required to determine the compatibility of the soil/geotextile system. As the Perth metropolitan area has only a limited variety of soils, the number of laboratory tests is not extensive.

1 INTRODUCTION

In Western Australia, geotextiles are increasingly used for filtering purposes, in place of conventional graded granular filters. Geotextiles are wrapped around aggregate or plastic core, and water flows across the geotextile to the core and dissipates into the system, in similar way as in graded granular filters.

Christopher & Fischer (1991) compiled a concise, up-to-date summary of the design criteria of filtration performance produced by various researchers. However, none of these criteria has been accepted as a standard design method, due to the lack of evidence or statistical data to prove the validity of any of these criteria on all types of soils. William & Luettich (1990) compared various filtration criteria with laboratory tests conducted, and discovered great discrepancies among the design methods and their laboratory test results.

Selecting a suitable geotextile for each geotechnical application is crucial as most applications are expected to be operating for a long period of time. Therefore, without a valid design criteria that is widely acceptable, laboratory tests are generally conducted for very critical applications where failure would be damaging. Laboratory tests are generally not conducted for non critical applications due to the high cost, and may result in high maintenance cost or repair cost. Hence, there is a need to perform laboratory testing economically to determine geotextile's compatibility to local soils for critical and non-critical applications.

There is a need to select suitable geotextiles for the local soil types. As the Perth metropolitan area has only a few varieties of soils, mainly sandy soils (Smith 1990), conducting a limited number of tests would cover most Perth soils. It was anticipated that standard test equipment could be developed at an economical cost and lead to a low cost on-going programme of soil testing for Western Australia.

Laboratory tests are necessary to determine compatible geotextiles with soils, unless there is a universal design criteria. Thus, in this project, an elaborate filtration test equipment is to be designed and commissioned, in an attempt to match suitable geotextiles to the local soils (Perth).

2 TEST TECHNIQUES

Few filtration test methods were reviewed for this project. They were the Gradient Ratio Test (Haliburton & Wood 1982), Long Term Test (GRI 1987), Hydraulic Conductivity Ratio Test (William & Abouzakhm 1989), Concentrated Flow Test (Legge 1990), Interface Flow Test (Legge 1990), Suspension Injection Filtration Test (Kellner & Matei 1991). All these methods have their own shortcomings.The test method adopted was a combination of a Gradient Ratio Test and a Long Term Test, also known as the Long Term Gradient Ratio Test (Halse et al 1987). Such test was suitable in this project due to the availability of time in performing this test.

Three stages of testing were conducted; Proving Trial Test, Variable Head Test, and Variable Fabric Test. Proving trial test was performed for the refinement of test equipment and test procedures.

Variable head test has four sets of three permeameters, each subjected to a different constant head of water. This was to investigate the hydraulic gradient influence on the soil/geotextile system.

Variable fabric test has four sets of three permeameters of various sizes (thickness) of geotextiles, and were tested under constant head to determine the appropriate geotextile for the type of soil tested. This type of test will be an on-going test for future research, to determine the most suitable geotextile for various soil types around Perth.

2.1 System Descriptions

The permeameter used was a modified version to the gradient ratio permeameter (see fig. 1) developed by Haliburton & Wood (1982), which also enabled a gradient ratio test to be conducted simultaneously with the long term test. Although the function of the permeameter is evident, the instrumentation of such test equipment is not well documented. Hence, the initial equipment consisted of only the basic requirements of the system. Refinements to the equipment were then introduced to account for all possible factors affecting the soil/geotextile system. The refinement of equipment was based on deductive evidence supported by the proving trial test.

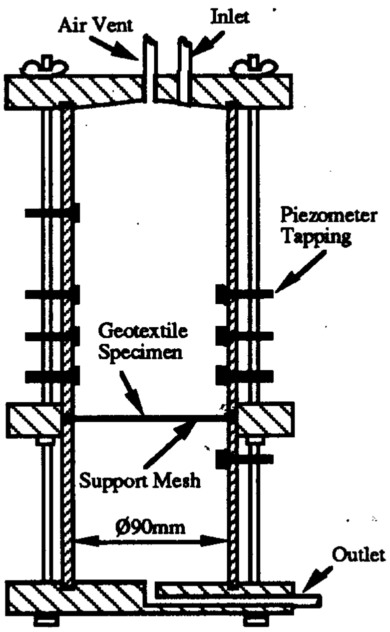

Fig. 1: A Permeameter Unit

The final equipment developed for this study consisted of 5 integrated parts: twelve permeameter units, constant head system, water recycling system, water quality control, and data collection. For more details on the instrumentation, refer to Chin (1993).

3 RESULTS ANALYSIS & INTEPRETATION

The geotextiles used were continuous filament, needled-punched, non woven geotextiles Three geotextile sizes used were Polyfelt TS22, TS500 & TS700 which have masses of 115g/m^2, 140g/m^2 & 280g/m^2 respectively. In this paper, GTnw1, GTnw2 & GTnw3 are used to represent the three sizes respectively.

The particle size distributions of the soils tested are as shown in fig. 2 below.

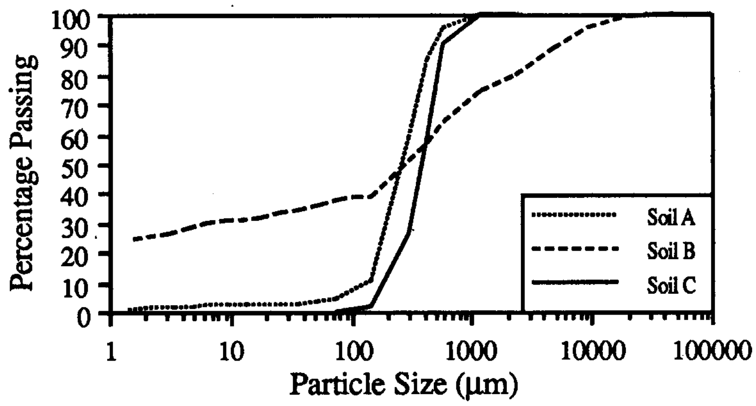

Fig. 2: Particle Size Distribution of Tested Soils

3.1 Surface Clogging of Soil Samples

Clogging of the top soil layer of the soil tested was encountered. This reduced the permeability of the top layer of the soil, and hence the discharge through the permeameter. The reduction in flow through the system deterred the evaluation of the filtration at the soil/geotextile interface which was the main objective of the tests.

During the proving trials, the flow through the permeameters ceased within 2-3 days. The soil sample had a hard crust surface which appeared to be the barrier. The test was continued after the removal of the soil surface, and soon surface clogging occurred again. This clearly shows that clogging occurred on the soil's surface.

One factor contributing to the clogged surface is an increase in quantity of fine particles being deposited on the soil's surface, which is largely due to the accumulation of impurities (fines) from tap water. A water recycling system with a filter has been implemented and eliminated the fines accumulation, but was inadequate in preventing the surface clogging completely.

Biological activity was the other major factor contributing to surface clogging. Micro-organism growth was concentrated on the surface due to the widely available food supply from the flow of water. Filtering of fine particles actually cut-off the massive food supply to the micro-organisms. Hence, micro-organism growth slowed down but was not completely eliminated.

A bromine solution was introduced as a disinfectant into the water supply and kept the micro-organism growth under control.

In Fig. 3, there was a reduction in permeability for the test on Soil C before the addition of disinfectant. When the disinfectant was injected into the water supply, there was a distinct increase in permeability after a short time lag.

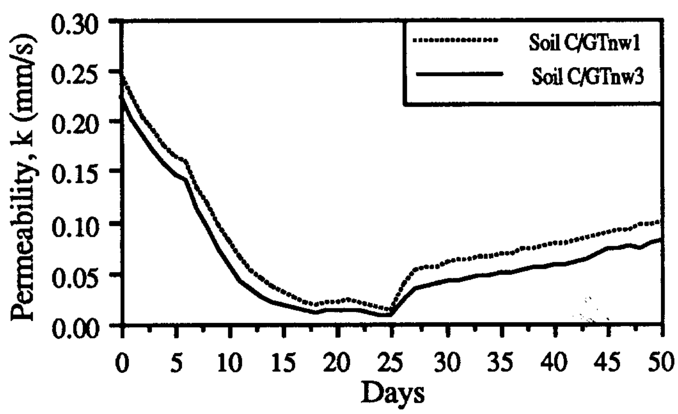

Fig. 3: Bacterial Influence on Soil Surface.

Waste from the micro-organisms can be created in a few ways. It could have been fungi producing wax-like substances which resulted in a non-wetting soil and reduced water seepage, or algae oxidising iron compounds in the water producing precipitants which clog the pores in the soil.

The micro-organisms influence appeared to be the main cause for surface clogging. However, other factors could not be ignored. These other factors include; the compaction effect, accumulation of fines and the creation of a surface crust due to high impact water force.

Micro-organisms influence in surface clogging is a common phenomena in laboratory filtration tests. Such problems have been mentioned briefly in a few papers (GRI 1987; Chen & Simons 1981). In actual field conditions, micro-organisms do not appear to cause clogging problems as concluded by Mlynarek et al (1990) after a 9 year survey on operational geotextiles. Only in leachate flow as in landfills that micro-organism clogging become a problem.

3.2 Influence of Hydraulic Heads on Filtration Test

The hydraulic gradient influences the seepage flow in soils where higher head corresponds to higher gradient, and higher seepage velocity. This has an influence on the migration of particles in a soil, which is more critical for non-cohesive soils than cohesive soils due to the absence of cohesive forces in non-cohesive soils.

Theoretically, high hydraulic gradient would tend to increase the possibility of particle migration. As the seepage velocity influences the migration of particles, it is evident that variable head influences the performance of the filtration test. Many research papers (Bhatia et al 1990; Qureshi et al 1990; Lawson 1990; Koerner & Ko 1982; Williams & Luettich 1990; Faure et al 1986) mentioned the hydraulic gradient used in the tests, but little has been done to investigate its influence on soil/geotextile systems, and hence, its influence on the results produced from such tests.

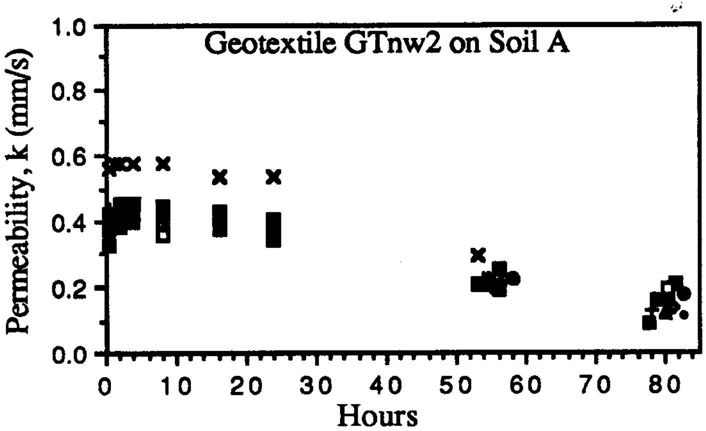

Fig. 4: Variable Head Test-Permeability at soil/geotextile interface

Sets of three test were conducted at four constant heads (775mm, 582mm, 378mm & 179mm). Fig. 4 is a typical permeability graph which indicates all twelve tests are very close together creating a band of curves. This signifies that permeability remains unchanged regardless of the four levels of constant head used. Hence, the head variation up to 775mm was insufficient to cause any change in the permeability of soil tested.

3.3 Filtration Performance of Variable Fabric Tests

As shown in fig. 5, Soil A and Soil C are compatible with the tested geotextiles except for the C/GTnw3 soil/geotextile combination. Graphs for compatible systems were approximately constant at 2000 hours. For Soil C/GTnw3 combination, the permeability decreased while the gradient ratio increased at 2000 hours, which indicated a clogging system.

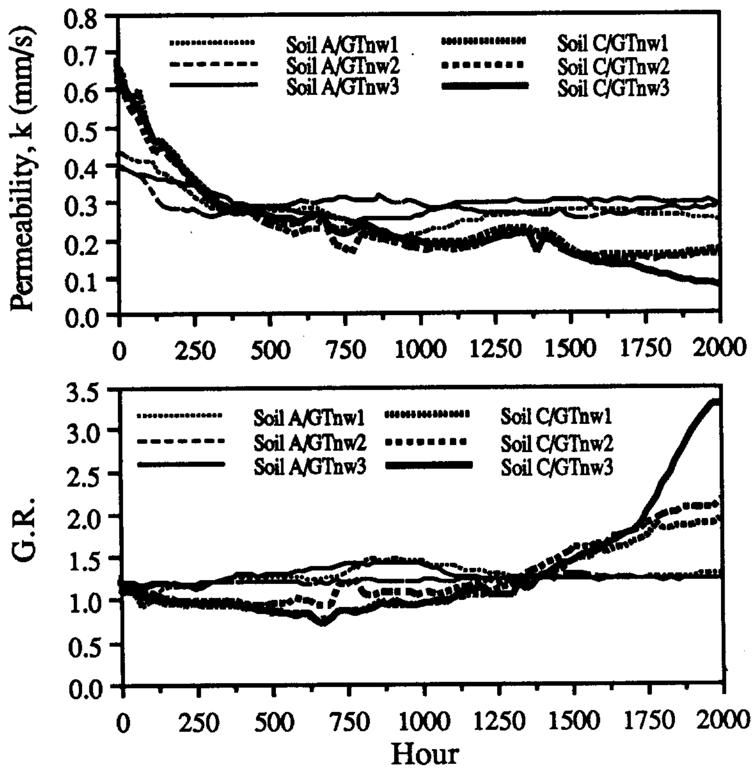

Fig. 5: Filtration performance of Soil A & Soil C.

For Soil B, fig. 6 indicates that the permeabilities of the soil/geotextiles systems are constant, but the gradient ratio for combinations Soil B/GTnw1 and Soil B/GTnw2 are increasing.

$$G.R. = \frac{k_{soil}}{k_{fabric}} \qquad (1)$$

Following the formula above, an increase in gradient ratio with a constant k_{fabric} (permeability at soil/geotextile interface) will results in an increase in k_{soil} (soil permeability). Instead of clogging which normally associated with high gradient ratio, piping have occurred. Fine particles were washed through the geotextiles and more fine particles were migrating towards the soil/geotextile interface. As particles washed through the geotextile were replaced by the migrating fines, K_{fabric} remained constant and K_{soil} increased. Hence, only geotextile GTnw3 is suitable for Soil B.

5 CONCLUSIONS

The results, analysis and discussions derived in the course of this study allow the following conclusions to be drawn.

(a) A complete filtration test equipment has been designed, tested and commissioned.

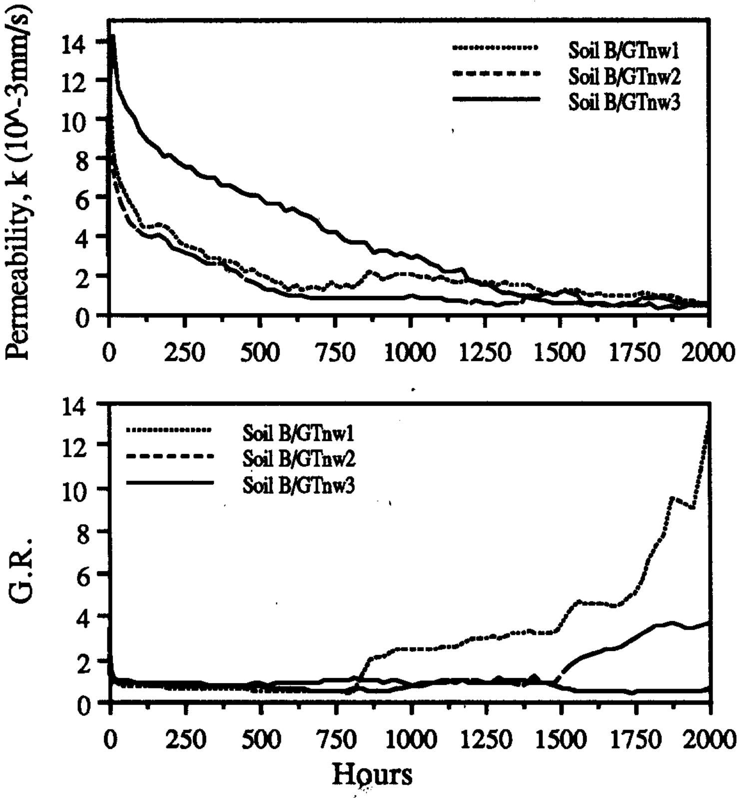

Fig. 6: Filtration performance of Soil B.

(b) Surface clogging occurred, inhibiting the filtration operation of the proving trial test. Two factors leading to surface clogging are the bacterial activities and the accumulation of fines. Apparently, micro-organism (bacterial) activity is the main factor causing surface clogging. It's existence in laboratory filtration test is not unusual.

(c) Variable head tests conducted indicate that the range of head (up to 775mm) used in the filtration test has little significance on the filtration test.

(d) Permeability graphs, together with gradient ratio graphs, produce an ideal form of evidence of filtration performance for soil/geotextile systems. A stable interaction system would produce permeability and gradient ratio tending to constant values.

(e) Analysis of the filtration performnces suggest that all three geotextiles tested are suitable for soil A, only geotextile GTnw3 is suitable for Soil B, and geotextiles GTnw1 and GTnw2 are suitable for Soil C.

More testing is recommended to include soil types at outskirt region of Perth metropolitan as well as specific soil type within Perth.

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