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FILTRATION AND DEGRADATION BEHAVIOUR OF SOME NONWOVEN GEOTEXTILES IN HONG KONG

CARACTERISTIQUES DE FILTRATION ET D'USURE DE QUELQUES GEOTEXTILES NON-TISSES TESTES A HONG-KONG

FILTEREIGENSCHAFTEN UND BESTÄNDIGKEIT EINIGER NICHT-GEWOBENER GEOTEXTILIEN IN HONG KONG

The Geotechnical Control Office of the Hong Kong Government tested nonwoven geotextiles from six manufacturers for filtration and degradation characteristics. A 300 mm diameter permeameter was used to observe filtration behaviour when the geotextiles were placed against a recompacted granitic soil. Geotextiles selected according to accepted filter design rules all formed stable filters during the 3 to 8-month testing period. Their behaviour was very similar to a conventional granular filter tested with the same soil in the large permeameter. The geotextiles had a variable response to outdoor exposure, however, with an 8 to 35% loss in tensile strength after 8 weeks exposure. Polyester, polypropylene, and polypropylene-polyethylene fabrics were tested.

Das staatliche Kontollbüro in Hongkong untersuchte nichtgewobene Geotextilien (Vliese) von sechs Herstellerfirmen auf Filtereigenschaften und Beständigkeit. Das Filterverhalten wurde studiert indem in einem Permeameter von 300 mm Durchmesser die Geotextilien auf ein wiederverdichtetes granitisches Lockergestein gelegt wurden. Bei den Geotextilien welche gemäss bewährten Filterbemessungs-verfahren ausgewählt wurden, bildeten sich während der 3 bis 8 monatigen Versuchsperiode überall stabile Filter. Das Verhalten dieser Filter glich stark demjenigen eines konventionellen, aus körnigem Material hergestellten, Filters welcher im grossen Permeameter mit dem gleichen Lockergesteinsmaterial getestet wurde. Die Geotextilien zeigten eine unterschiedliche Reaktion auf Witterungseinflüsse. Nach 8-wöchiger Exponierung wiesen alle einen 8 bis 35 prozentigen Verlust an Reissfestigkeit auf. Es wurden Textilien aus Poyester, Polypropylen und aus Polypropylen-polyethylen untersucht.

INTRODUCTION

Urban development of steep slopes in Hong Kong leads to extensive hillside excavation and the use of numerous retaining walls. These slope works routinely include subsurface drains to remove groundwater that is fed by intense rainstorms. The subsurface drains often provide a crucial margin of stability in an otherwise landslide prone area (1). Trench or interceptor drains are often employed, as are blanket or chimney drains behind retaining walls (2, 3), but arrays of horizontal drains and drainage caissons have also been used (4, 5).

Subsurface drains in Hong Kong must function in a variety of residual soil conditions, and granular filters have traditionally been chosen to facilitate groundwater removal and prevent internal soil erosion. More recently, geotextiles have been used as filters in subsurface drains, often with significant reductions in construction difficulty and cost. Their filtration behaviour with tropically weathered residual soils, however, is not well documented. The only available filtration test data for geotextiles used in Hong Kong soils is given by Lawson (6, 7, 8).

A review of the use of geotextile filters in Hong Kong has been undertaken by the Geotechnical Control Office. This paper reports on two aspects of the review, namely the filtration behaviour of several nonwoven geotextiles used in conjunction with a recompacted granitic soil, and the degradation behaviour of some synthetic fabrics during outdoor exposure in Hong Kong. The latter aspect was identified as an important consideration for the longterm performance of subsurface drains.

FILTRATION TESTS

Several large permeameters were constructed for filtration testing (Figure 1). Each permeameter was 300 mm diameter by 600 mm high, and could accommodate a 260 mm high soil specimen in the upper half. A geotextile could be clamped between the upper and lower parts, and drainage aggregate could be placed in the lower half. A permeameter could accommodate seven small piezometers tapped into the soil specimen, located from 2.5 mm to 250 mm above the geotextile interface. The piezometer tubes were 3 mm diameter, and each one extended radially inward one-third of the cell diameter.

The remoulded granitic soil used in these tests was a widely graded silty sand (Figure 2), with a uniformity coefficient (D_{60}/D_{10}) of 80. (The uniformity coefficient increased to 800 when a dispersant was used in the gradation test.) The soil was compacted in the permeameter to a dry density of 1.7 Mg/m^3, equivalent to 95% of the Proctor maximum dry density for this soil, at a moisture content of about 16%. This resulted in soil specimens with a permeability of 3 to 6×10^{-8} m/sec after saturation.

The geotextile to be tested was placed against the soil after it had been compacted into the top part of the permeameter. The permeameter was then temporarily inverted and a uniform 20 mm crushed aggregate was poured onto the geotextile and compacted. The geotextile was therefore probably under a relatively low compressive stress during the test, but the actual stress was not measured. Finally, the permeameter was reinverted and then saturated in an upward direction.

In all the filtration tests, a constant water head of 1.88 m was applied to the top of the soil specimen, which created an overall hydraulic gradient of approximately 7 through the soil. This was considered to be somewhat more severe than the typical field situation in Hong Kong, where subsurface drains are rarely subjected to hydraulic gradients greater than 1.

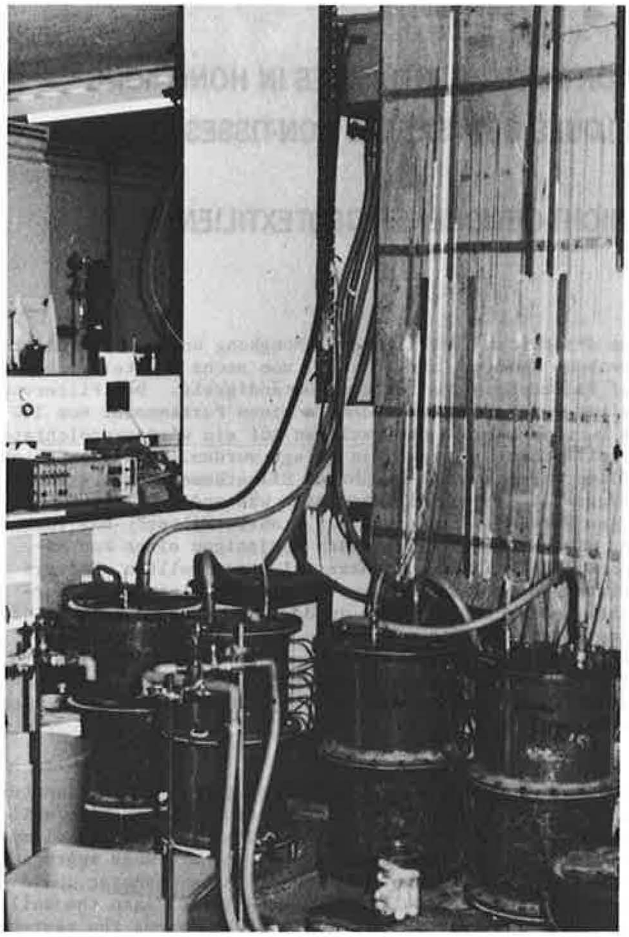

Figure 1 - Large Diameter Permeameters for Filtration Testing

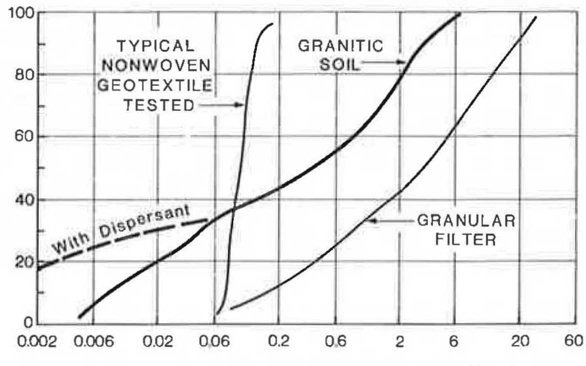

Figure 2 - Grading of the Soil, Granular Filter and Geotextiles

The six nonwoven geotextiles listed in Table 1 were selected for testing in the permeameter. These geotextiles varied in weight between 105 and 210 g/m^2, and in thickness from 0.3 to 2.1 mm (at 0.35 kPa normal stress), but they all had a pore opening size, O_{90}, between 0.1 and 0.3 mm at low normal stresses. A typical pore size curve for these geotextiles is shown in Figure 2.

Table 1 - Filtration Test Results

Filter Tested	Test Duration (hours)	Modified Gradient Ratio
Bidim U24	3710	0.01
Polyfelt TS500	2880	0.12
Stabilenka T100	2800	0.09
Tafnel U40	5510	0.43
Terram T1000	4190	0.04
Typar 3401	1940	1.05
Granular filter		
• Test 1	2500	0.10
• Test 2	2060	0.06

Filter design rules for geotextiles usually relate the pore size of the geotextile to the soil particle size, and are generally given in the form

$$O_i = C\,D_n \qquad (1)$$

where O_i is the indicative opening size of the geotextile (often taken as O_{90} or O_{95}), D_n is the soil particle diameter below which lie n% of the soil particles, and C is a constant or variable that depends on D_n, the soil grading, the hydraulic conditions and other factors (8). Upper bound values for C are specified to limit soil piping, and lower bound values to limit clogging of the filter and hydraulic head build up (9, 10, 11, 12, 13, 14, 15). On the basis of these filter design rules, the upper bound value (piping limit) of O_{90} for a geotextile used in conjunction with this granitic soil should be not greater than 2 mm. There is less certainty about the lower bound value (permeability limit) of O_{90}, but this should be in the range 0.02 to 0.2 mm. For the geotextiles actually selected for the filtration tests, O_{90} ranged from 0.1 to 0.3 mm, and these geotextiles were therefore well below the piping limit but closer to (or on) the permeability limit.

The durations of the filtration tests on the six geotextiles varied from 3 to 8 months (Table 1). A supply of deaired water could not be maintained for such an extended period, so tap water filtered through a geotextile was utilised. This undoubtedly had some slight effect on the test results.

The test results are summarised in Figure 3, which shows the system permeability variations with time. Permeability changes, both increases and decreases, occurred in the early part of each test while a filter zone was developing within the soil near the geotextile interface. All the tests then stabilised at a permeability equal to or greater than the original soil permeability, indicating satisfactory filtration behaviour.

Detailed observations were also made of the hydraulic regime within the soil specimen during each test, and a typical result is shown in Figure 4. Some nonlinearity was evident in the initial head loss through the specimen, due to specimen inhomogeneities. The nonlinearity markedly increased during the test as a more permeable filter zone developed in the soil near the geotextile. The

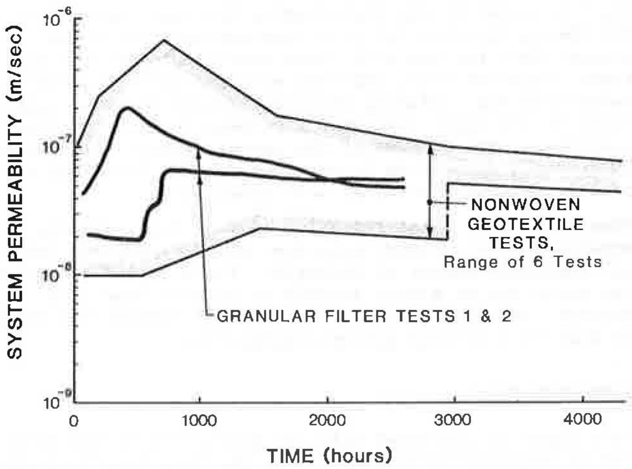

Figure 3 - Summary of Filtration Test Results

permeable zone extended up to 150 mm from the geotextile interface in some of the tests (Figure 4). This would indicate that fine soil particles migrated through the geotextiles during the tests, but this migration was not directly quantified. Head losses across the geotextile itself were in all cases negligible.

When a test had stabilised, a modified gradient ratio (MGR) was computed. The MGR, as defined by Scott (16), is

$$MGR = i_f / i_s \qquad (2)$$

where i_f is the hydraulic gradient in the filter zone (including the geotextile) and i_s is the hydraulic gradient in the unaffected soil. An MGR < 1 indicates that the filter zone is more permeable than the original soil and that the geotextile is an acceptable filter; MGR >1 indicates that a clogged fabric is hindering the flow. The MGRs for all the tests are given in Table 1, which shows that five of the geotextiles were clearly successful and one was marginal for the granitic soil tested.

COMPARATIVE GRANULAR FILTER TESTS

Two filtration tests on a granular filter were conducted

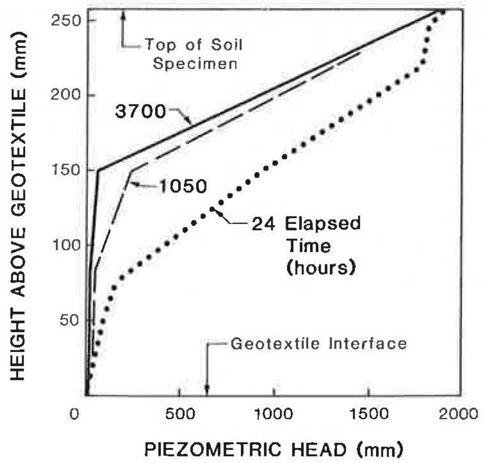

Figure 4 - Head Loss within the Soil, Bidim U24 Test

for comparison with the tests on geotextiles. The same soil and permeameters were used, but the geotextile was deleted and the drainage aggregate in the base of the permeameter was replaced by the granular filter. The granular filter was a sandy gravel (Figure 2) which conformed to common filter design rules (2).

The granular filter performed very similarly to the nonwoven geotextiles tested (Figure 3 and Table 1). A filter zone also developed within the soil for a significant distance from the interface (Figure 5), as had been observed in the geotextile tests. Minor head losses within the granular filter (up to 70 mm) were observed during the tests, but these did not persist after the system had stabilised.

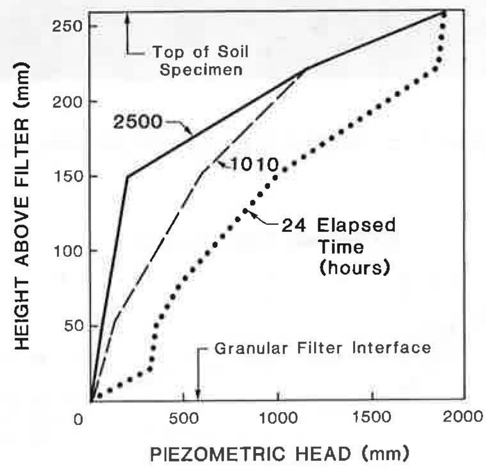

Figure 5 - Head Loss within the Soil, Granular Filter Test

OUTDOOR EXPOSURE TESTS

Six nonwoven geotextiles were exposed to the weather on a building roof top in urban Hong Kong (Figure 6). Four of the geotextiles tested were the same as those used in the filtration tests, and two were somewhat different. The exposure tests were conducted in 1982 on geotextile samples collected in late 1981. These samples were placed on wooden frames which faced south and were tilted at 45°. The atmospheric conditions during the eight-week test are given in Table 2.

Table 2 - Atmospheric Conditions during Outdoor Exposure Test

Mean air temperature	19°C
Average daily fluctuation	4.5°C
Maximum air temperature	27°C
Minimum air temperature	13°C
Total rainfall	80 mm
Mean relative humidity	82%
Total bright sunshine	192 hrs.
Total global solar radiation	580 MJ/m^2

The grab tensile test was used to determine the degradation in strength of the geotextiles with exposure. The results are shown in Figure 7. Most of the geotextiles lost about 15% of their strength during the test, but one fabric degraded much more rapidly. No clear relationship

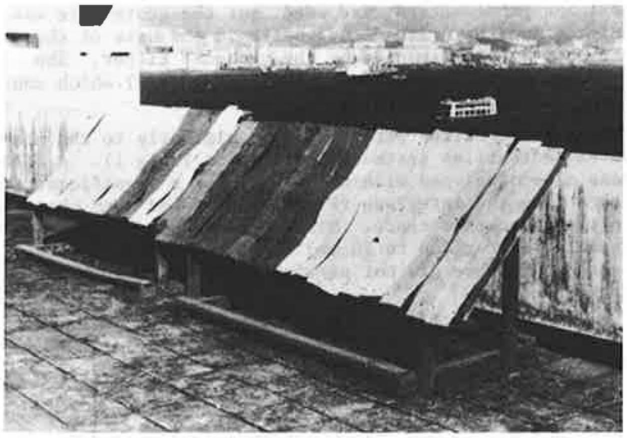

Figure 6 - Outdoor Exposure Test in Hong Kong

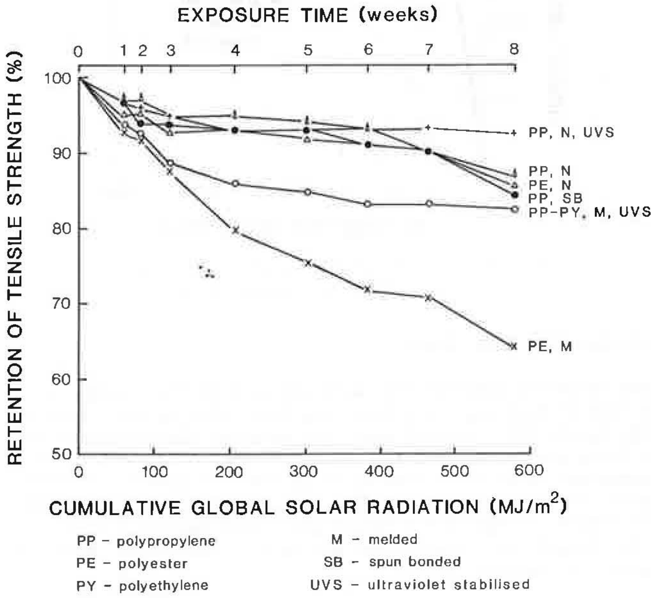

Figure 7 - Degradation Behaviour of Some Nonwoven Geotextiles in Hong Kong

was found between degradation behaviour and polymer type.

The outdoor exposure test was conducted from mid-February to mid-April, a period during which the sunlight conditions were not particularly severe. About twice this amount of solar radiation would usually be received in a similar period during mid-summer (July). Also, because of the urban location of the tests, it is possible that air pollution from nearby vehicles or factories had some effect on the outcome.

CONCLUSIONS

The nonwoven geotextiles tested proved to be successful filters for a recompacted, widely graded granitic soil under steady flow, low head conditions. They possessed filtration behaviour directly comparable to that observed for a granular filter tested under the same conditions. All the geotextiles had pore openings well below the piping limit for the soil, they were placed against already compacted soil, and they were probably subjected to relatively low confining stresses. While the test conditions do not fully represent the range in expected field conditions, the outcome of the tests suggests that properly designed geotextile filters can be used in common tropically weathered residual soil conditions.

When exposed to solar radiation in Hong Kong, samples of nonwoven polypropylene, polyester and polyethylene fabrics all lost some amount of strength. Their varied performances could not be simply related to polymer type. In general, therefore, outdoor exposure of geotextiles should be kept to a minimum during construction.

ACKNOWLEDGEMENTS

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