Evaluation of transmissivity characteristics of some geosynthetics under normal stress

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ABSTRACT: Geosynthetics have been widely used for drainage and filtration in various areas of geotechnical applications. The porous structure of nonwoven geosynthetic makes its use more preferable for filtration (cross-plane flow) and drainage (in-plane flow). However, the in-plane flow of a nonwoven geosynthetic, due to its compressible nature under stress, is a function of its thickness. The objective of this paper is to examine the in-plane flow (transmissivity) characteristics of different nonwoven geosynthetic under stress, for its possible use as drainage media for reinforced slopes. The transmissivity of geosynthetics is determined using a radial flow device. This paper presents the effect of a nonwoven geosynthetic type, number of geosynthetic layers and the influence of confining stress on the in-plane flow characteristics of geosynthetics. The confining stress was increased in intervals from 0 to 200 kPa. The in-plane flow of nonwoven geosynthetics was observed to decrease with an increase in confining stress. The transmissivity increased with an increase in the number of geosynthetic layers. Results of this study indicate possible use of nonwoven geosynthetic as a drainage media along with a suitable geogrid (to form a geocomposite), to enhance pore water pressure dissipation in a slope constructed with a relatively impermeable soil.

1 INTRODUCTION

Geosynthetics have been widely used in various civil engineering applications. The nonwoven geosynthetics, having porous structure, has enabled its use in situations of cross-plane as well as in-plane flow and enhanced its application for dissipating pore water pressures in embankments, fills and fabric retaining walls, eliminating hydrostatic pressure behind retaining walls and dissipating seepage forces in earth and rock-fill slopes, to name a few. DeBerardino (1992) has highlighted the use of nonwoven geosynthetics and prefabricated drainage composites as an effective and alternative subsurface drainage media to traditional construction materials. The problem of drainage is more severe with impervious soils leading to development of excess pore pressures and instability of the structure. Cohesionless soils are highly preferred backfill materials due to its high permeability. However, its lack of availability and large transportation costs forces the need to use locally available impervious soil as backfill, provided sufficient measures are taken/provided to reduce the development of pore water pressure. The use of a nonwoven geosynthetic having good drainage properties along with a reinforcement media as, together forming a geocomposite as seen in Fig. 1, may help to reduce the developed pore water pressures for reinforced soil structures with low-permeable soils (Yasuhara et al. 2002). The drainage application of geosynthetics involves transverse flow of liquid and hence the evaluation of transmissivity of such fabrics is very important.

Numerous studies have been carried out by various researchers to determine the in-plane flow characteristics of geosynthetics using devices based on different principles. Majority of the studies have been focused on the transmissivity of geonets and prefabricated geocomposite drains used for accelerating the rate of consolidation and landfills applications (Ghosh and Yasuhara, 2004, Hara et al. 2007). In this paper, an attempt has been made to determine the transmissivity characteristics of specially designed geocomposites, for its possible use as a drainage medium for reinforced slopes and walls constructed with low-permeable backfill. The geocomposites referred herein increase the stability of a structure by virtue of two primary functions: tensile reinforcement with the help of geogrid and drainage for reducing pore pressures with the help of non woven geosynthetic [Liu et al. 2009 and Tolooiyan et al. (In press)]. Some geosynthetics selected for the present study represent the commercially available materials whereas some fabrics with reduced weight were purposely selected for modeling of geocomposites, based on scaling consideration given by Viswanadham and König (2004) for its use as a model material in physical model tests.

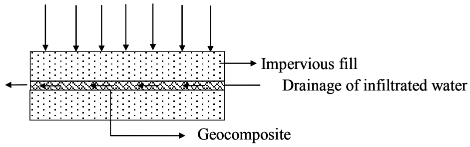


Fig 1. Schematic of geocomposite application for a reinforced slope with impervious fill

The objective of the present study is to determine the in-plane flow of nonwoven geosynthetic layers and developed geocomposites under increasing normal stress using a radial setup for its possible use as a drainage media for low-permeable soils for centrifuge modeling. The scaling considerations for in-plane permeability have also been presented briefly which are required to be validated further.

2 EVALUATION OF TRANSMISSIVITY

The ease of flow through a porous medium is expressed by the coefficient of permeability. For geosynthetics, the coefficients of permeability are usually normalized by its thickness, t_g, to give the permittivity, ψ and transmissivity, θ, for the cross-plane and in-plane flows, respectively. The in-plane permeability, k_h, and transmissivity, θ, are expressed as:

$$\theta = k_h t_g = \frac{q}{W}\frac{L}{h} \qquad (1)$$

Where, θ = transmissivity (m^2/s), k_h = in- plane permeability coefficient (m/s), q = flow rate (mL/s), h = head loss in the flow direction (m), t_g = thickness of the geosynthetic (m), W = width of the geosynthetic (m), i = hydraulic gradient (dimensionless) = Δh/L, L = length of geosynthetic (m).

The model geocomposite material is a combination of nonwoven geosynthetic and a reinforcement material in the form of geogrid and needs to be scaled down to serve the dual function of drainage and reinforcement. The model reinforcement materials used are miniature versions of commercially available geosynthetic materials. For similarity of in-plane flow characteristics of model and prototype geocomposite material, $\theta_m = \theta_p$ where, suffix m and p represent corresponding parameters for model and prototype. The physical dimension t_g (thickness) of geosynthetic is scaled down by a scale factor N. For similitude to be achieved between model and prototype, the scale factor for the in-plane permeability coefficient (k_h) of geosynthetic should be N times that of prototype, as given in Eqn. 2 (using Eqn. 1).

$$(k_h)_m = N(k_h)_p \qquad (2)$$

The in-plane flow (transmissivity) of geosynthetics under confined loading conditions has been determined according to ASTM D6574 (2006) using a radial flow device shown in Fig. 2.

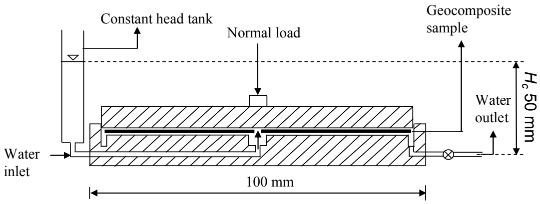


Fig 2. Schematic of transmissivity set-up for geocomposites

3 TEST MATERIALS AND METHODS

3.1 Materials

Three different types of nonwoven geosynthetics, G1, G3 and G5 and reinforcing geosynthetic materials G2, G4 and G6 were used to form three geocomposites G1G2, G3G4 and G5G6 geocomposites. Table 1 gives the specifications of the geosynthetic material and developed geocomposites. The selection of the model geocomposite was based on the tensile strength-strain criterion for reinforcement material and transmissivity characteristics of the drainage material. Due to influence of several parameters of geosynthetics on the performance of geocomposite, perfect scaling-down of the prototype materials to the desired scale factor may not be feasible and hence a model material representing the characteristics of the existing commercially prototype geocomposites is developed.

3.2 Test method

A schematic representation of a radial in-plane flow test apparatus as shown in Fig. 2 was used to evaluate the transmissivity. A 100 mm diameter circular sample with a hole in the centre, was prewetted in water and placed in the test device. Water was allowed to flow in the sample from the center to facilitate in-plane flow through the geosynthetic material radially outward. The discharge (q) collected per unit time (mL/s) was measured and the transmissivity of geosynthetic samples was evaluated.

Table 1 Specifications of Geotextiles and Geocomposites used

Geosynthetic Legend	Composition	Thic-kness (mm)	Linear density (g/m^2)
G1	NPNW	1.7	113
G2	Woven PP	-[a]	75
G3	HBNW	0.21	38
G4	Hexagon M	-[a]	-[a]
G5	NPNW	1.35	60
G6	Square M (3x3 mm)	-[a]	-[a]
G1G2	NPNW + Woven	-[a]	-[a]
G3G4	HBNP + M	-[a]	-[a]
G5G6 (L)	NPNW + M (L)	-[a]	-[a]
G5G6 (U)	NPNW + M (U)	-[a]	-[a]

NPNW - Needle punched nonwoven; HBNP - Heat bonded nonwoven; PP – Polypropylene; M – Mesh; U – Upper; L – Lower; -[a] – Not determined/Not reported.

4 TEST RESULTS AND DISCUSSION

The transmissivity *(θ)* of geosynthetics G1, G3, G5 and developed geocomposites G1G2, G3G4, G5G6 is determined using a radial setup. The influence of number of geosynthetic layers, geosynthetic type, the drainage component of geocomposite and the position of the reinforcing layer is studied at normal stresses corresponding to 0, 20 kPa, 50 kPa, 100 kPa and 200 kPa respectively.

4.1 Influence of number of geosynthetic layers

Tests were carried out for one and two layers of nonwoven geosynthetic G1 and woven geosynthetic G2, the results of which are shown in Fig. 3. The transmissivity for 2 layers of nonwoven geosynthetic G2 is higher than 1 layer, whereas for woven geosynthetic G2, the transmissivity for two layers is lower than 1 layer. This could be attributed to the different orientation of yarns of the 2 layers of woven samples in the radial setup, leading to obstruction in the flow path of the geosynthetic material.

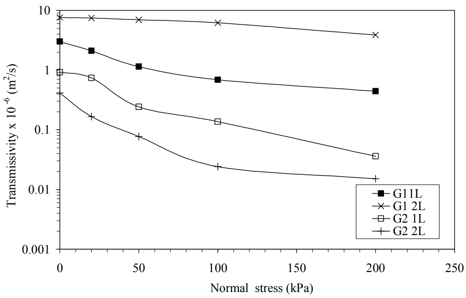


Fig. 3. Variation of transmissivity with number of geosynthetic layers

4.2 Influence of geosynthetic type

Fig. 4 gives the variation of transmissivity for nonwoven geosynthetics G1, G3 and G5 having different linear density and thickness. The transmissivity observed for thermally bonded nonwoven is lower than needle punched nonwoven G5 upto normal stress of 50 kPa. This may be attributed to the different apparent opening sizes of the two nonwoven samples, which has not been determined in the present study.

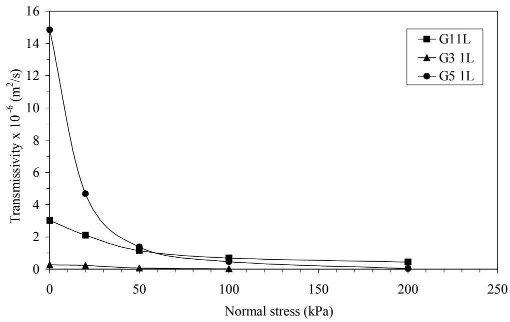
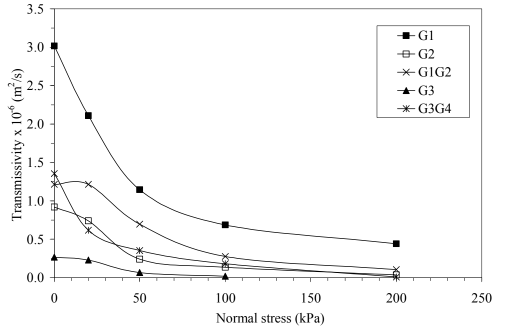


Fig. 4. Variation of transmissivity for different types of nonwovens

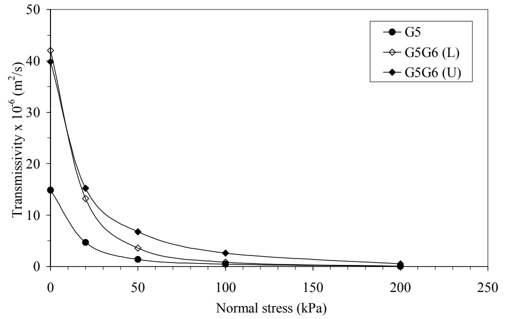
4.3 Influence of geosynthetic component and its position

To arrive at a model geocomposite material, different geocomposites were developed and their transmissivity were compared with their individual components. Figs 5a-5b show the transmissivity of developed geocomposites and its individual geosynthetic materials. The transmissivity of a geocomposite G1G2, Fig 5a, formed using a needle punched nonwoven G1 and woven geosynthetic G2, lies in between the transmissivity values of its individual components G1 and G2. The transmissivity of geocomposite G1G2 is lower than its nonwoven component G1, contradictory to that observed for geocomposites G3G4 and G5G6, Fig 5b, for which the transmissivity of geocomposite material is higher than its nonwoven component. The geocomposites G3G4 and G5G6 have a mesh with high percentage open area as a reinforcement material that might have resulted in an increase in the transmissivity of these geocomposites.

To further evaluate the significance of the position of reinforcement layer on the transmissivity of geocomposites, tests were carried-out by changing the positions of reinforcement layer G6 for the geocomposite G5G6. The geocomposite with the mesh placed on top G5G6 (U) gives higher transmissivity values for all the normal stresses compared to when the mesh is placed on bottom side G5G6 (L) for normal stress upto 50 kPa. This indicates that the position of reinforcement layer might also influence the in-plane flow capability of a geocomposite which needs to be further investigated.



a) Geocomposite G1G2, G3G4 and its component geosynthetic



b) Geocomposite G5G6 and nonwoven geosynthetic G5

Fig 5 Influence of geocomposite component on transmissivity

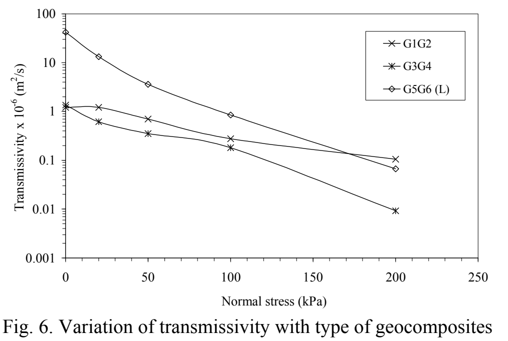


Fig. 6. Variation of transmissivity with type of geocomposites

4.4 Influence of geocomposite type

Fig 6 shows the transmissivity of developed geocomposites under the influence of normal stress. The in-plane flow for geocomposites G1G2 and G5G6(L) having needle punched nonwoven, as one of the components is higher compared to geocomposite G3G4 with a heat bonded nonwoven. Hence to improve the drainage performance, the needle punched nonwoven may be more suitable compared to heat-bonded nonwoven.

5 CONCLUSIONS

The transmissivity of nonwoven geosynthetics is found to decrease with normal stress and number of nonwoven geosynthetic layers. Geocomposites developed using a needle-punched nonwoven gave good transmissivity results and may be more suitable as drainage media for impervious fills. The transmissivity of developed geocomposites in the present study has been determined in isolation and similar behaviour may not be observed when placed in soil due to presence of soil particles. Its behaviour in soil needs to be investigated further. For similitude to be achieved, the transmissivity for the model and prototype nonwoven geosynthetic material should be same. The geocomposite developed using model and prototype nonwoven gives almost similar transmissivity but differs in tensile strength due to its scaling. Hence the developed model geocomposite can be used for centrifuge and physical model test at 1g and Ng after considering the scaling considerations. Further research on the effect of apparent opening size of nonwoven geosynthetic on the transmissivity of developed geocomposites is warranted.

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