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# Transmissivity of Geotextiles and Geotextile/Soil Systems

# Transmissibilité transversale de géotextiles et systèmes géotextile/sols

The necessity of determining in-plane permeability or transmissivity is critical for all applications of in-plane water flow using geotextiles. This paper describes a test method and apparatus which accurately models in-situ behavior, uses relatively large samples (61.0 cm x 30.5 cm), has the capability of testing under high normal pressures and can examine the performance of the fabric sandwiched between soils as occurs in the natural situation. It was found that transmissivity decreases exponentially with normal pressure but, for the fabrics tested in this study, is never completely cut off. Pressures up to 96 kPa (equivalent to approximately 10 m of water) were evaluated. Typically, the transmissivity of a 600 gm/sq. m weight geotextile is equivalent in its hydraulic capability to 2.5 cm of sand. The presence of clay soil on both sides of the fabric somewhat limits its performance. It is concluded that bulky geotextiles of the type evaluated in this study are well suited to transmit water in the in-plane direction.

La nécessité de déterminer la transmissibilité transversale est importante dans toutes les applications de l'ecoulement de nappes d'eau transversales utilisant les geotextiles. Cet article décrit une méthode et l'appareil qui (1) très précisément représentent le comportement "in-situ", (2) utilise relativement de grands échantillons (61,0 cm x 30,5 cm), (3) a la capacité de tester sous hautes pressions normales, et (4) peut examiner la performance du tissu pressé entre des sols comme cela se présente dans la situation naturelle. Il a été trouvé que la transmissibilité diminue exponentiellement avec une pression normale mais, pour les tissus experimentés dans cette étude, n'est jamais complètement coupée. Des pressions jusqu'à 96 kPa furent évaluées. Typiquement, la transmissibilité d'un poids de $600gm/m^2$ de geotextile est équivalante dans sa capacité hydraulique à 2,5cm de sable. La présence d'argile des deux côtés de tissu diminue un peu sa performance. En conclusion, les géotextiles volumineux du genre évalués dans cette étude sont bien équipés pour transmettre de l'eau.

## INTRODUCTION

The essential hydraulic aspects of geotextiles are their ability to pass water perpendicular to their plane and, for some, their ability to move water within their plane. This latter aspect of in-plane permeability of geotextiles, first noted by Leflaive and Puig (1), is the focus of this paper. The uses for geotextiles to transmit water in this manner are necessary in a number of practical situations. These situations include the following, which underscore the importance of the subject. See Giroud (2) for further details.

- interceptors for road drains
- drain wells to decrease consolidation times
- eliminate hydrostatic pressure behind retaining walls
- dissipate seepage forces in earth and rock slopes
- as chimney drains in earth dams
- as drainage galleries in earth dams
- dissipate pore water pressures in embankments and fills
- dissipate pore water pressures in fabric retaining walls
- dissipate pore water pressures in encapsulated soil systems
- transmit water from beneath railroad ballast
- guide subsurface water away from frost action areas
- break capillary zones in frost heave areas
- dissipate gas pressures beneath pond liners

The particular property of the geotextiles which will be measured in this study is called transmissivity ($\theta$), which is the in-plane permeability multiplied by the fabric thickness and carries the units of area per unit time. The reason for including the thickness in the value $\theta$ is that the pressures exerted on the fabric cause a fabric compression, which can be quite large, and the term transmissivity is a method of including this characteristic. In most cases "$\theta$" will be plotted against the stress "$\sigma$" exerted against the fabric thereby simulating in-situ conditions as close as possible.

The paper will describe the experimental apparatus which was used and then present a number of test results using fabric alone and in combination with soil over a wide range of normal stresses. The conclusions will include a summary of the entire project to date.

## EXPERIMENTAL PROCEDURE

The number and variety of physical configurations that one can devise to measure transmissivity are many, e.g., see reference (3) for the Swiss approach to these measurements. All, however, are based upon Darcy's Law with a constant, or falling head system and are somewhat modeled after laboratory permeability measurements of soil. One added, and necessary, feature is that the fabric must be subjected to a measurable normal stress.

The system we have devised is shown in the photograph and diagrams of Figure 1. Here, the lower base plate measuring 77.5 cm x 30.5 cm supports the fabric, which in turn supports the upper assembly consisting of an inverted aluminum channel connected to a plastic water container. The upper aluminum channel, which supports the load used to develop normal stress in the fabric, measures 61.0 cm x 30.5 cm. After the load is placed, the assembly is bolted together so that water flow can only occur horizontally in the fabric between the aluminum plates. Water is supplied via the plastic tank at constant heads of 7.6, 15.3, 22.9 or 29.3 cm. At each value of normal stress, a series of four tests are performed at each of the available heads. The water which passes in the plane of the fabric is collected at the downstream end of the apparatus in a trough and measured per unit time. Calculations then proceed using the following relationships:

$$q = k_p \, i \, A$$

$$q = k_p \frac{h}{L} (w \, t)$$

$$\frac{q}{w} = (k_p \, t) \frac{h}{L}$$

$$\theta = (q/w)/(h/L)$$

where

$q$ = flow rate ($m^3/s$)
$k_p$ = in-plane permeability (m/s)
$h$ = head forcing flow (m)
$L$ = length of fabric (m)
$w$ = width of fabric (m)
$t$ = thickness of fabric (m)
$\theta = k_p t$ = transmissivity ($m^2/s$).

Graphically, the procedure reduces to plotting (q/w) versus (h/L) values and measuring the resulting slope for the desired value of transmissivity ($\theta$). This value is then plotted against the normal stress on the fabric (or soil/fabric/soil) system and behavioral trends are observed.

TESTS RESULTS

In all of the test results reported in this paper, the geotextile used was a needle punched, nonwoven, monofiliment polypropylene fabric (in various thicknesses) marketed by Crown Zellerbach under the trade name "Fibretex" (4).

The results are categorized into experiments which evaluate the effect of initial fabric thickness, high normal stresses, tests on the transmissivity of sand for comparison purposes and then a series of tests with soil on each side of the fabric. Additional detail is contained in reference (5).

(a) Effect of Normal Stress and Initial Fabric Thickness

This initial series of tests was aimed at determining the basic question of how much water a specific geotextile will transmit under varying amounts of pressure, i.e., normal stress. The preliminary step of measuring flow rate versus the head forcing flow is shown in Figure 2. This gives an indication of the amount of data scatter which, as seen, is relatively small. The slope of these lines is the transmissivity which results in Figure 3 when plotted against stress. Here it is seen that stresses up to 93 kPa (approximately 10 m of water pressure) were imposed and a near constant behavior in $\theta$ resulted at stresses beyond 30 kPa. The resulting flow as a function of initial fabric thickness was predictable in that the thicker fabrics resulted in proportionally higher transmissivities at all stress levels.

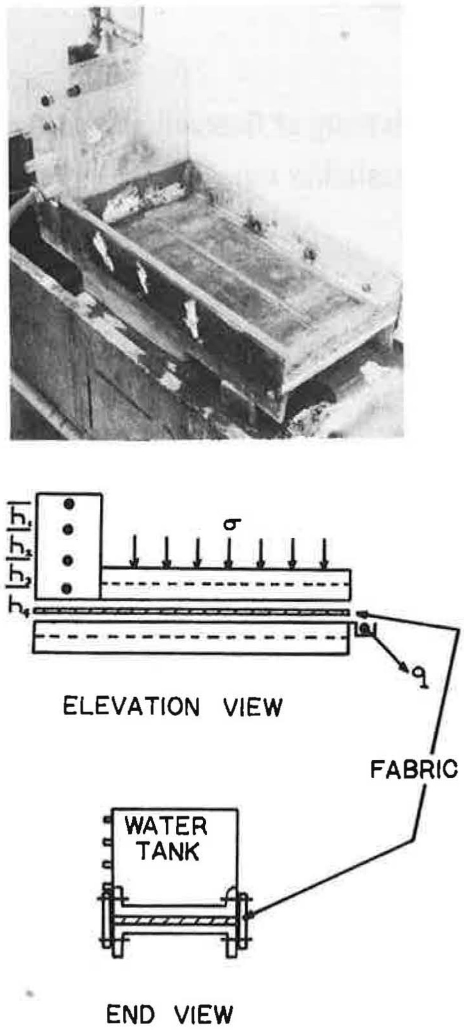


Fig. 1. - Photograph and Cross Section Diagrams of Transmissivity Measuring Device Used in This Study.

(b) Fabric Transmissivity Compared to Sand

In many of the applications mentioned in the introduction, fabrics are being used in place of sand. Thus it seems appropriate to compare the transmissivity of various thicknesses of sand to that of a geotextile. For this series of tests a medium graded sand (subrounded shape, effective size of 0.17 mm, coefficient of uniformity of 3.5, and classified as a SP soil) was used and tested at initial thicknesses of 1.3, 2.5 and 5.1 cm. The response is shown in Figure 4. Superimposed on the sand behavior curves is the 9.6 mm thick fabric response. Here it can be seen that fabrics are noticeably more compressible than sand and for typical highway drainage situations, say at 10 kPa stress, the 9.6 mm thick fabric is approximately equivalent to 5.1 cm of sand.

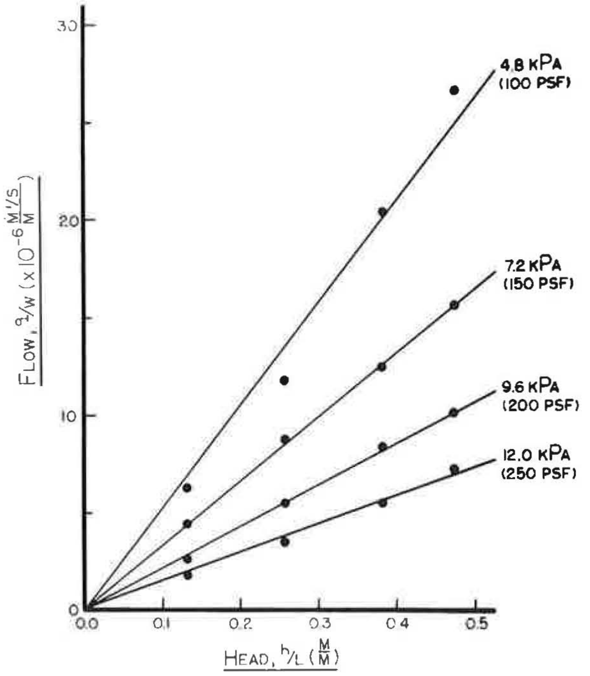


Fig. 2. - In-plane Water Flow versus Head Forcing Flow at Various Applied Stresses on Fabric (Note: the Slope of These Lines is the Transmissivity, θ).

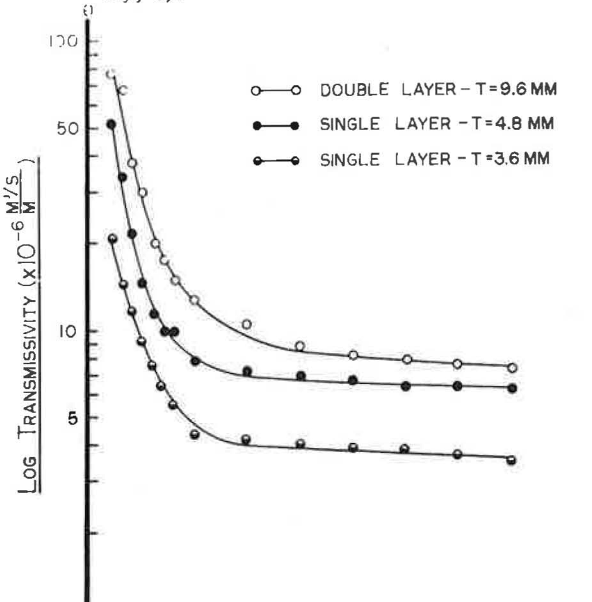


Fig. 3. - Transmissivity versus Applied Stress for Various Thicknesses of Nonwoven Needled Polypropylene Fabric.

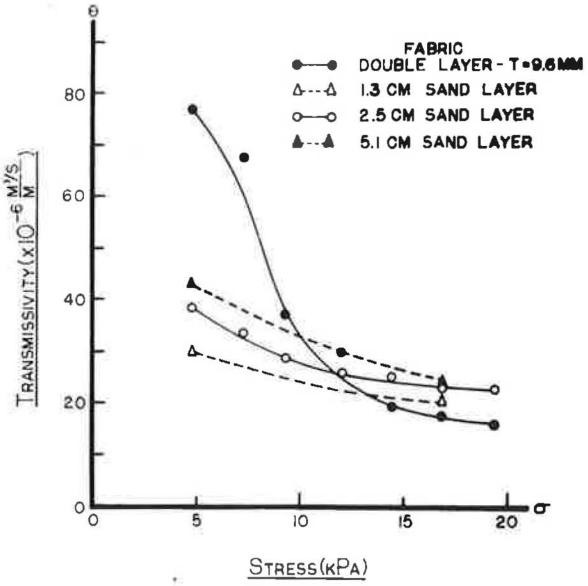


Fig. 4. - Transmissivity versus Applied Stress for Various Thicknesses of Sand Compared to Transmissivity of 9.6 mm Thick Fabric.

(c) Soil/Fabric/Soil Tests

The natural setting for fabrics is obviously with soil on each side of it and in order to assess the transmissivity under this condition a series of soil/fabric/soil tests were performed. A 0.7 cm thickness of soil was placed on the base of the test apparatus, then the fabric, and finally a second layer of soil 0.7 cm thick was placed on top of the fabric. The system was then assembled in the conventional manner. For these tests four different fine grained soils were blended with resulting particle size distribution curves shown in Figure 5. The transmissivity test results are given in Figure 6 for the fabric by itself, then for the four different blended soil/fabric/soil systems. Seen in these curves is the loss of flow capacity with increased amounts of clay soil content. There appears to be only a minor loss of transmissivity up to 15% clay content, but for higher clay contents, the loss is substantial. In these latter tests there was a noticeable infiltration of the soil into the fabric.

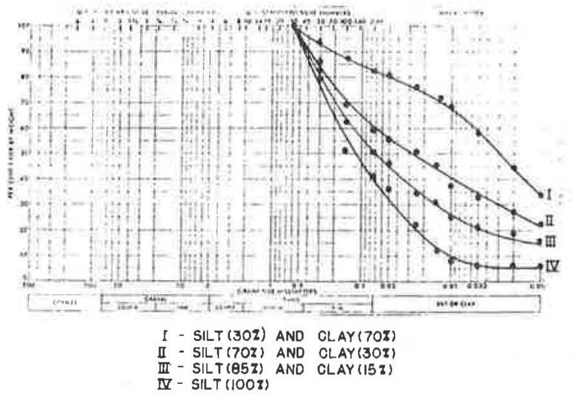


Fig. 5. - Particle Size Distributions of Soils Used in Soil/Fabric/Soil Portion of This Study - see Data of Figure 6.

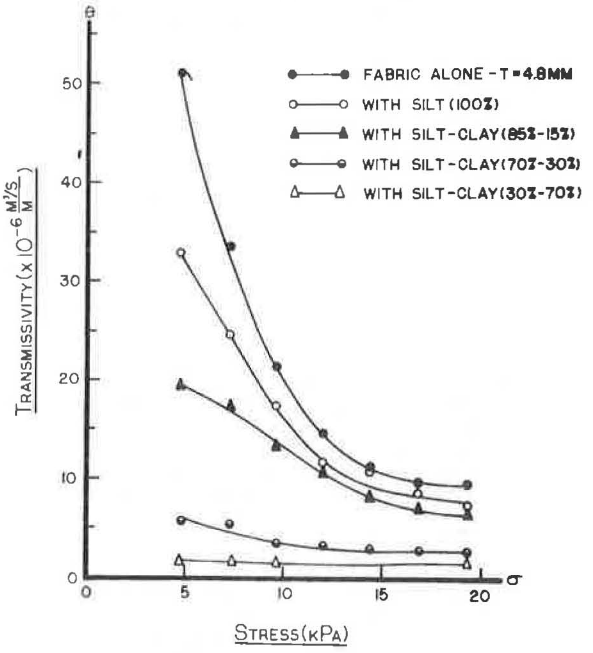


Fig. 6. - Transmissivity versus Applied Stress for Soil/Fabric/Soil Systems Compared to Fabric by Itself.

## SUMMARY AND CONCLUSIONS

Using a laboratory test setup which closely simulates in-plane water flow in geotextiles in the field, the transmissivity (in-plane permeability times thickness) of a nonwoven, needle punched polypropylene fabric was evaluated. Major findings of the study were as follows:

- transmissivity decreases to a constant value with increasing normal stress applied to the fabric,
- the transmissivity is never cut off completely even up to stresses of 93 kPa,
- transmissivity increases with increasing initial fabric thickness,
- at normal stresses of 10 kPa, the transmissivity of a 9.6 mm initial thickness geotextile is equivalent to approximately 5.1 cm of sand,
- soil on both sides of a geotextile decreases its transmissivity, but only soils with very high clay contents (>30%) are considered to be detrimental.

In conclusion, it is felt that the use of bulky geotextiles is a logical and effective means of conveying water in a wide variety of construction applications. Many of these applications were previewed in the introductory section.

## ACKNOWLEDGEMENTS

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