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Results of Permeameter Tests on Statically Loaded Geotextiles
Résultats d'essais de perméabilité sur des géotextiles chargés statiquement

A special permeameter has been developed and constructed for the determination of the permeability both normal to the plane and in the plane of geotextiles. A description of the apparatus and the findings of an earlier test series is given in brief. The main part of the paper describes the results of permeameter tests performed on three geotextiles loaded up to 800 kN/m^2. The tests for flow normal to the fabric have been evaluated in terms of the permittivity. Similarly the tests for flow in the plane of the fabric are presented in terms of the transmissivity. In the examined stress range the permittivity varies considerably more for the needle-punched geotextiles than for the spun-bonded geotextile. It is also interesting to note that the coefficient of permeability normal to the plane and in the plane is the same for the needle-punched geotextiles, but that for the spun-bonded geotextile a significant difference exists according to the test results.

On a développé et construit un perméamètre spécial pour la détermination de la perméabilité normale au plan et dans le plan des géotextiles. La description de l'appareil et les résultats d'une première série d'essais sont donnés brièvement. La partie principale de l'article décrit les résultats d'essais de perméabilité sur 3 géotextiles chargés jusqu'à 800 kN/m^2. Les essais pour un débit normal au plan du géotextile ont été évalués en terme de permittivité. De manière similaire, les essais pour un débit dans le plan du géotextile sont présentés en terme de transmissivité. Dans le domaine des pressions examiné, la permittivité varie considérablement plus pour les géotextiles aiguilletés que pour le géotextile thermosoudé. Il est aussi intéressant de noter que le coefficient de perméabilité normal au plan et dans le plan est le même pour les géotextiles aiguilletés, alors qu'il existe une différence significative pour le géotextile thermosoudé comme le montrent les essais.

INTRODUCTION

A number of interesting contributions to the International Conference on the use of fabrics in geotechnics, Paris, 1977, dealt with the permeability of geotextiles and the development of testing procedures for its determination (e.g. 1, 2, 3, 4, 5). Meanwhile, a good deal of additional research has been done in several institutions and laboratories and much progress has been made in this specific area (6, 7, 8, 9).

At the Institute of Foundation Engineering and Soil Mechanics, ETH Zurich, preliminary investigations on the determination of the permeability of geotextiles started in 1978 (10, 11). These investigations were undertaken in cooperation with the Swiss Technical Commission on Geotextiles and arrived at formulating the requirements for a special permeameter. The performance of this special permeameter as an investigation tool should cater for the following requirements:

1. Reproducible test results.
2. Tests with flow of water normal to the plane and in the plane, the latter if possible in both directions, without removing the applied pressure on the sample or disturbing it.
3. To run tests both without and with soils.
4. To perform the test under static load, measuring the deformations.
5. Possibility of testing woven as well as nonwoven or compound geotextiles.
6. Size of the specimen of about 0.01 m^2 or larger.
7. Hydraulic gradients up to 50.

The apparatus was designed and constructed at the Institute of Foundation Engineering and Soil Mechanics, ETH Zurich and the first tests were performed in 1980.

APPARATUS AND PRELIMINARY TEST RESULTS

In figure 1 an overall view of the apparatus is given and in figure 2 a schematic diagramme is shown. A more detailed description of the apparatus is contained in (10, 11), and it is therefore limited to some of the essential features in this paper. The apparatus is based on a closed, temperature controlled circuit using demineralized deaired water which allows a flow both normal to the plane and in the plane of the geotextile. In the permeameter shown in figure 2 the rectangular geotextile sample is loaded between two pistons. The pistons contain filter plates made of quartz sand. The hydraulic head above and below the geotextile is measured by a total of eighteen pairs of piezometers.

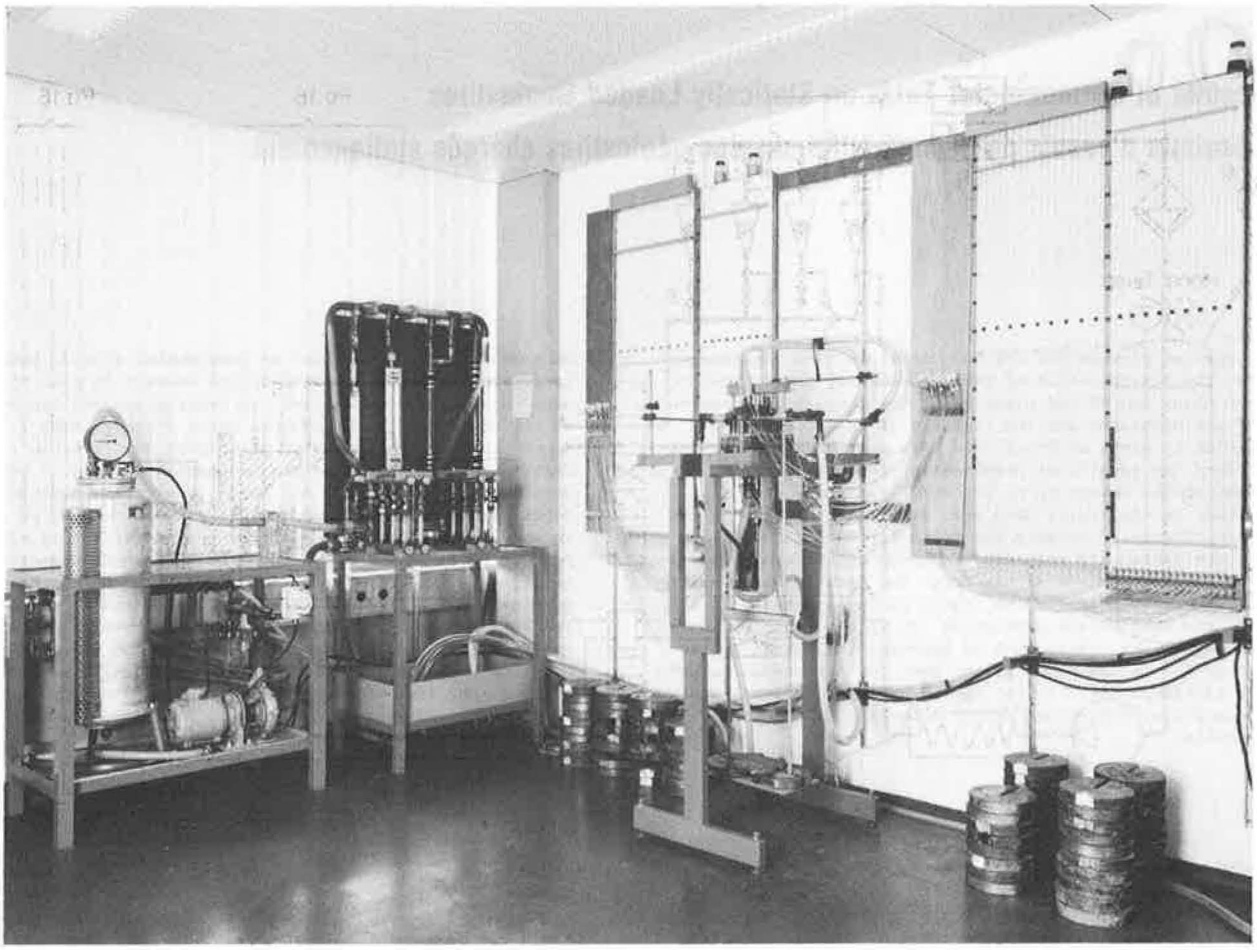

Fig. 1 Apparatus for the investigation of the hydraulic properties of geotextiles.

Fourteen pairs are located inside the area of 0.01 m^2 through which the vertical flow passes; four pairs are located outside this area and are used for the horizontal flow only.

Preliminary tests (10, 11) have shown that the coefficient of permeability is dependent on the hydraulic gradient. It is therefore important to perform tests and to compare test results at small hydraulic gradients as they are usually met in practical applications of geotextiles. Further, tests both for the permeability normal to the fabric and in the plane of the fabric have shown that the flow is significantly influenced by the normal stresses which are applied to the fabric.

PERMEAMETER TESTS NORMAL TO THE PLANE OF THE GEOTEXTILE

Three typical non-woven geotextiles have been selected for these tests. They may be characterized as follows:

geotextile 1: μ = 270 g/m^2, 100% polyester, needle-punched, unmodified, continuous filament.

geotextile 2: μ = 250 g/m^2, 100% polyester, needle-punched, staple fibre felt, resin bonded.

geotextile 3: μ = 200 g/m^2, 100% polypropylene, spun-bonded, continuous filament.

In order to assure small hydraulic gradients and laminar flow several sheets of geotextiles (up to 10) were placed in the permeameter. The tests were performed at effective normal stresses in the range of 20 kN/m^2 to 800 kN/m^2. At each pressure at least five determinations were made and the mean value was calculated. The results were obtained in terms of the permittivity according to

$$\Psi = \frac{q}{\Delta h \cdot A} \quad [s^{-1}] \tag{1}$$

where: q = rate of discharge; Δh = loss of head per sheet of geotextile; A = area for normal flow (0.01 m^2).

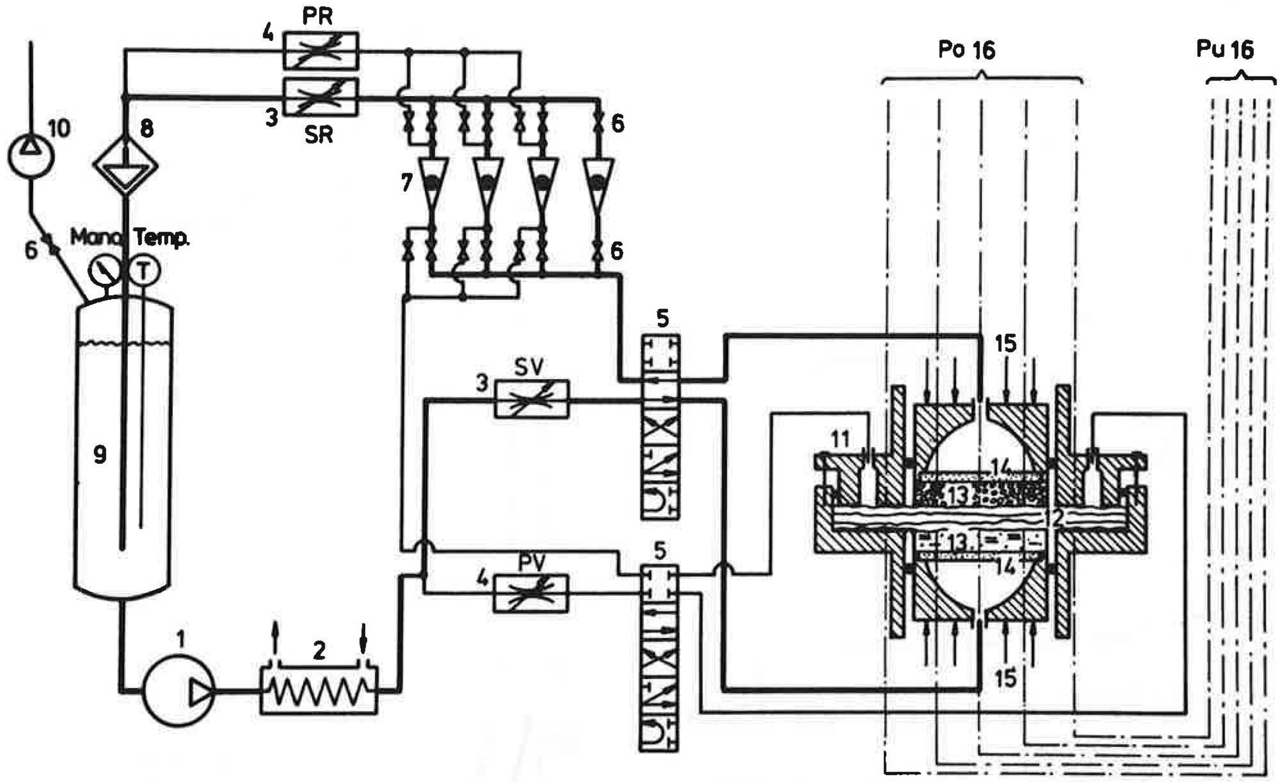

Fig. 2 Schematic diagramme of the apparatus. 1, water pump; 2, heat exchanger with thermostatic control; 3, throttle valve, flow normal to the plane of the fabric: SV, feed line; SR, return; 4, throttle valve, flow in the plane of the geotextile: PV, feed line: PR, return; 5, control valve; 6, shut-off valve; 7, flow meter; 8, filter for flushed out soil particles; 9, air chamber; 10, vacuum pump; 11, permeameter; 12, geotextile; 13, soil samples a and b; 14, filter plate; 15, applied static loading; 16, piezometer measuring tubes: Po, above the geotextile; Pu, below the geotextile.

From the permittivity the normal permeability k_{no} has been calculated:

$$k_{no} = \Psi \cdot T_g \qquad [ms^{-1}] \qquad (2)$$

where: T_g = thickness of geotextile (one sheet).

The values of the permittivity Ψ are plotted as a function of the effective vertical stress σ' (Fig. 3). The corresponding k_{no} values are given in Figs. 5, 6 and 7. From the values given in the graphs the following variations in the permittivity and in the normal permeability may be calculated in the observed stress range (20 - 800 kN/m^2).

Table 1. Variations in the permittivity and in the coefficient of normal permeability.

geotextile	variation in Ψ	variation in k_{no}
1	2.4	6.0
2	1.9	6.1
3	1.7	2.7

Two observations can be made from table 1: The variations in Ψ and in k_{no} are larger for the needle-punched geotextiles 1 and 2 than for the spun-bonded geotextile 3. Secondly, the variation in Ψ is considerably smaller than the variation in k_{no}. Therefore, the permittivity can better be considered as a constant material property over a given range of normal stresses than the coefficient of normal permeability.

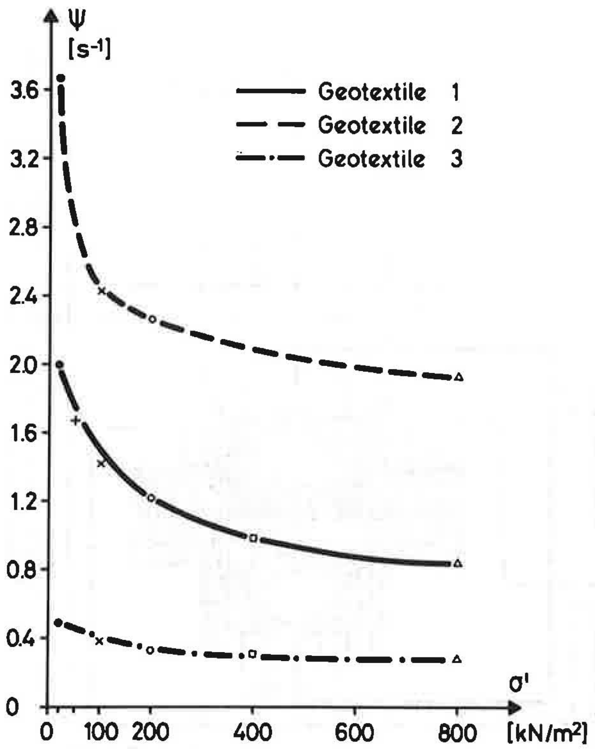

Fig. 3 Permittivity Ψ as a function of normal stress σ'.

PERMEAMETER TESTS IN THE PLANE OF THE GEOTEXTILE

These tests were performed on samples with a loaded breadth of about 230 mm and a length of 80 mm, and again on several sheets of geotextiles. For each of the investigated stresses in the range of 20 kN/m^2 to 800 kN/m^2 at least five determinations were made and the average values calculated. The test results are plotted in terms of the coefficient of permeability in the plane of the geotextile k_{po} in Figs. 5, 6 and 7.

The transmissivity has been evaluated according to

$$\theta = \frac{q \cdot L}{\Delta h \cdot B} \quad [m^2\ s^{-1}] \tag{3}$$

where: q = rate of discharge per sheet of geotextile; Δh = loss of hydraulic head; L = length of the flow path; B = breadth of the geotextile.

The coefficient of the permeability in the plane of the geotextile has been obtained from

$$k_{po} = \frac{\theta}{T_g} \quad [m\ s^{-1}] \tag{4}$$

where: T_g = thickness of geotextile (one sheet).

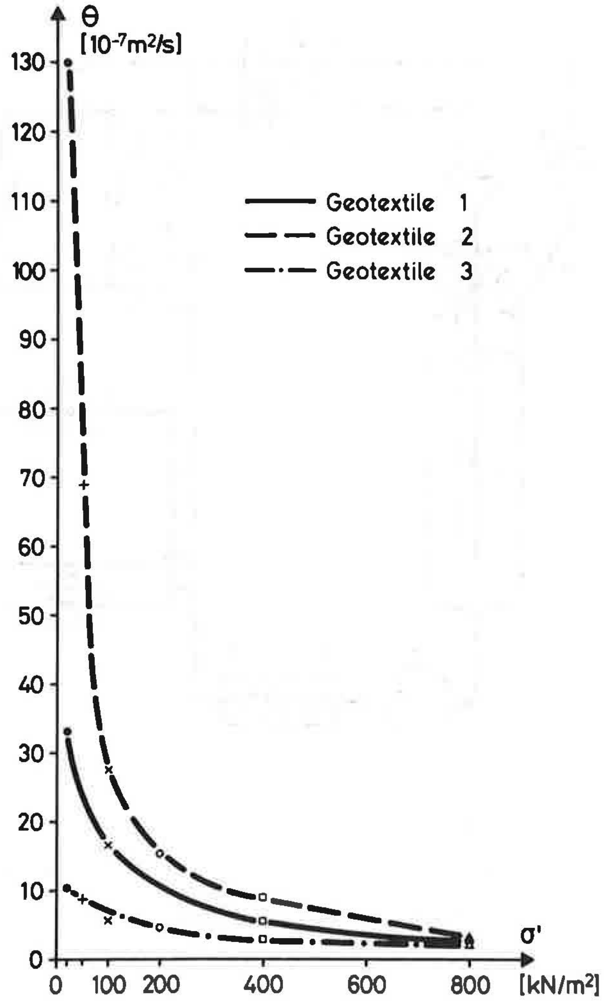

Fig. 4 Transmissivity θ as a function of normal stress σ'.

From the plotted values the following variations may be calculated:

Table 2. Variations in the transmissivity θ and in the coefficient of the permeability in the plane of the geotextile.

geotextile	variation in θ	variation in k_{po}
1	11.8	5.5
2	44.8	13.7
3	5.2	4.3

The influence of the normal stress acting on a geotextile is most significantly shown by the transmissivity, and it is quite obvious that the influence of the normal stress on the transmissivity may not be neglected. This influence is more pronounced for the needle-punched geotextiles 1 and 2 than for the spun-bonded geotextile 3.

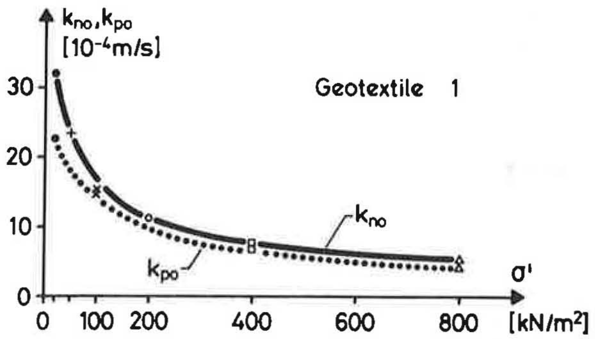

Fig. 5 Permeability k_{no} and k_{po} as a function of normal stress σ', geotextile 1.

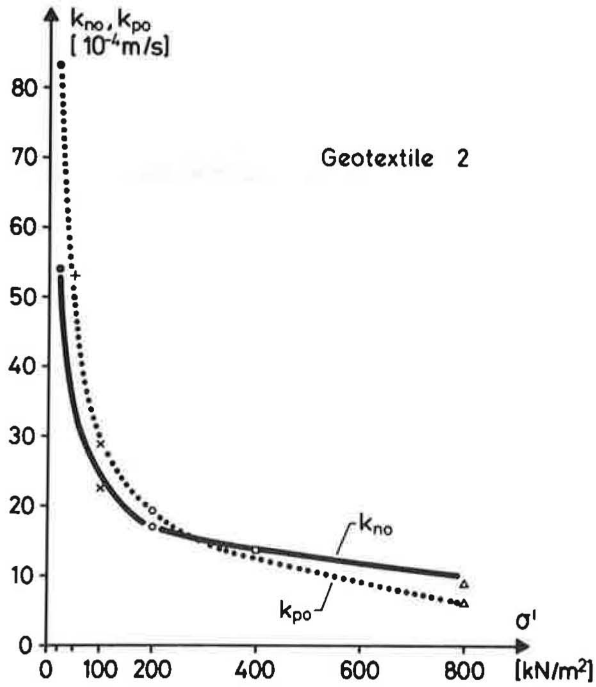

Fig. 6 Permeability k_{no} and k_{po} as a function of normal stress σ', geotextile 2.

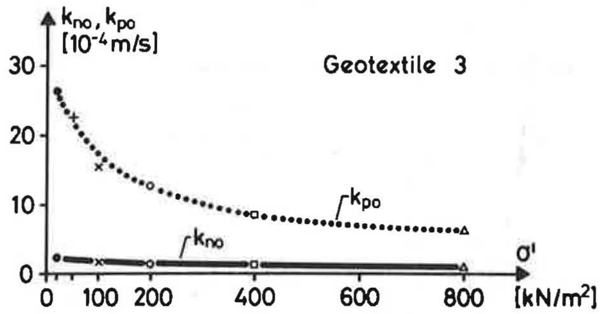

Fig. 7 Permeability k_{no} and k_{po} as a function of normal stress σ', geotextile 3.

CONCLUSIONS

From the performed permeameter tests normal to the plane and in the plane of the geotextile the influence of the normal stress acting on the geotextile has been shown to be important. The permittivity is less sensitive with respect to the normal stress than the transmissivity. Needle-punched geotextiles show greater variations than the spun-bonded geotextile. From the comparison of the coefficients of permeability normal to the plane and in the plane of the geotextile it may be said that needle-punching results in about the same coefficients, whereas spun-bonding appears to give a relatively higher permeability in the plane (factor 10) as shown in Fig. 7. This result will be checked by additional tests in a different permeameter which allows tests to be performed on a single geotextile sheet.

ACKNOWLEDGEMENTS

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