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On Hydric Properties of Geotextiles

Sur les propriétés hydriques des géotextiles

In Romania the first unwoven geotextiles have been manufactured in 1974 mainly from waste synthetic materials. Paper presents some characteristics of most used types as well as a method to determine pore mean size based on water retaining properties. This procedure was verified by microscopic tests and was found more realistic than sand sieving. For stuying normal and in-plane permeabi - lity an original oedopermeameter was developed, allowing measurements with geotextiles submitted to various pressures, thus modelling actual conditions in the ground and inside earthworks. The device is provided also with a water desaeration system which improves the quality of tests. The contamination of geotextiles by soil parti - cles was studied both for low and high gradients ; the results proved the advantages of geotextiles as compared with classical inverted filters also from this viewpoint.

Les premiers géotextiles non-tissés ont été fabriqués en Roumanie en 1974 surtout à partir de déchêts. On présente les caractéristiques des types les plus utilisés ainsi qu'une méthode pour calculer les dimensions des pores basée sur les caractéristiques de retention de l'eau Ce procédé, verifié par essais au microscope, s'est avéré plus réaliste que le tamisage du sable normalisé. La perméabilité transversale et dans le plan a été étudiée avec un oedoperméamètre original, qui permet des mesures aux géotextiles soumis à différentes pressions, modélant ainsi les conditions réelles dans l'ouvrages. Le dispositif est doué d'un système de désaération de l'eau qui améliore la qualité des résultats. La contamination des géotextiles a été étudiée pour différents gradients hydrau - liques ; les résultats ont confirmé les avantages des géotextiles envers les filtres classiques aussi de ce point de vue.

1 INTRODUCTION

In the field of foundations and earthworks the occurrence of geotextiles was much expected because, unlike granular materials, besides filtration and drainage capacity, they also possess tensile strength and separation ability /1/.

These properties, as well as advantages resulting from material and time savings, efficience and safety increasing, diminishing of earthwork mass, and simplifying of quality inspection, could explain the fact that practical application of geotextiles overpassed the studies dedicated to their properties and behaviour.

Thus in Romania the first unwoven geotextiles have been produced in the year 1974 from abnormal synthetic threads recovered from chemical and textile factories. There were the following materials :

NETESIN, made of polypropylenic, polyesteric, and polynitrylacrylic fibres, obtained by defibration and consolidated by stitching with a strong thread ;

TERASIN, made of the same fibres as NETESIN, but consolidated by interstitching and gluing with a synthetic resin named ROMACRIL L.N.1 /2/.

Later on geotextiles were produced also from new - manufactured long propylene fibres consolidated by wo - ving, as for example MADRIL /2/.

In order to design a structure containing geotextiles it is necessary to know the hydric and mechanical properties of these materials /3/. In this paper the research works concerning the hydric properties of some Romanian geotextiles are described.

2 SUCTION AND PORE SIZE DISTRIBUTION OF GEOTEXTILES

Examination by binocular microscope showed that Romanian geotextiles consist of fibres of about 20 to 30 microns, larger voids existing in-between ; when the material is saturated with water, some occluded air bubbles also remain in the voids (Fig.1). Due to this fact the synthetic geotextiles show capillary phenomena, whereas suction forces are small and correspond to a water head of several centimetres /4,5/.

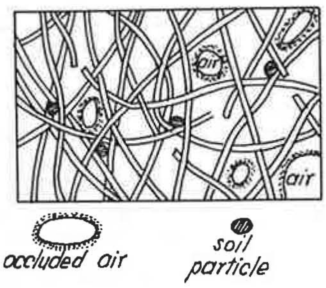

Fig.1. NETESIN extracted from an existing work - seen at the binocular microscope.

For knowing the pore size distribution, in contrast with current procedures based on sieving normalized sand or glass fractions, authors resorted to suction-moisture content curves by which geotextiles are characterized as capillary-porous systems. It is known that suction represents the deficit of water pressure in the voids of a porous body as against atmospheric and is usually expressed as cm water head (h) or by the sorptional index pF = lg h /6/. The water retention curves were determined by u - sing suction plate or pressure membrane devices in the range of pF = 0 to pF = 4.8 (0 to 6 MPa) (Fig.2).

The existence of a nearly-horizontal sector of suction moisture content curves in the range of low suction (pF = = 1 to pF = 2), where moisture content exceeds 10 to 15 %

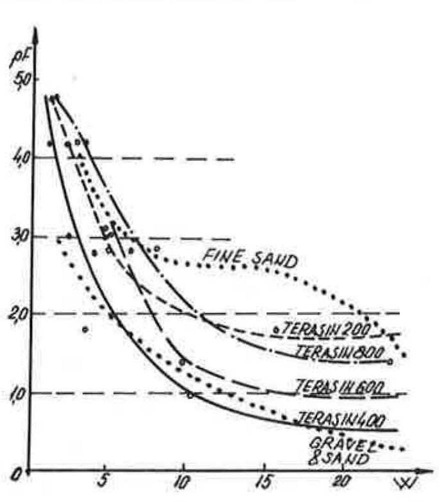

Fig.2. Suction - moisture content curves for Romanian geotextiles.

proves that most of water is located in relatively small pores (0.03 to 0.3 mm). Studies proved that natural fibres display an obviously higher retention capacity than synthetic fibres, therefore the latter ones behave like coarse granular soils (sand and gravel) which are used to inverted filters.

Synthetic geotextiles, like granular mineral materials, retain water especially due to pore capillarity, but in contrast with coarse soils, the saturation moisture content (for pF = 0) of geotextiles is extremely large , reaching as much as 1300 % forTERASIN.

Starting from the relation between the diameter of pores d_p (cm) and the suction h (cm) needed to empty them out /6/:

$$h = \frac{0.3}{d_p} \qquad (1)$$

it results that the retention curve represents in fact the distribution of pore dimensions and furnishes a good characterization of the pore system of the material. Any change in this system would induce a change also in the water retention curve.

If retained water is expressed in terms of degree of saturation S_r (%), the retention curve may be represented on a semi-logarithmic diagram like the particle size distribution (Fig.3).

In order to characterize in the same time also the soils in contact with geotextiles all these data were plotted in the third quadrant of the "print" diagram on which the soils used in experiments have been represented. The "print" is a simple geometrical figure combining particle size distribution and plasticity diagrams and used to soil identification /7/. By representing both materials on the same chart all basic information is available on a single picture. As it can be seen from Fig.3, Romanian geotextiles made from synthetic fibre wastes have similar pore size as those produced abroad - i.e. most of pores are larger than 0.03 mm. It must be also observed that the pore size distribution determined by sieving is not realistic, as it shows much finer dimensions than actual ones, because geotextile fibres hinder - by friction or adhesion - the passing through of sieved particles.

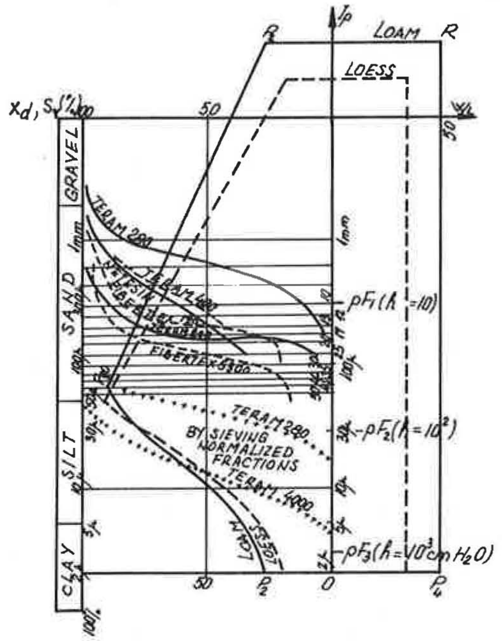

Fig.3. Identification charts ("prints") of examined soils and geotextiles.

3 NORMAL AND IN-PLANE PERMEABILITY OF GEOTEXTILES

In order to measure the permeability of geotextiles an oedopermeameter has been realized in two variants (Fig. 4). It has an essential advantage,i.e. the self-deaeration of circulating water, thus avoiding the formation of occluded air bubbles and the spreading of measurement results. The removing of air was obtained by the set-up

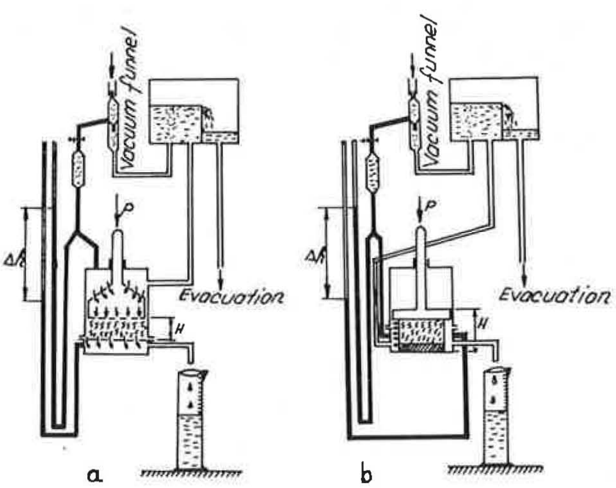

Fig.4. Schetch of oedopermeameter.
a) Measuring normal permeability.
b) Measuring in-plane permeability.

sketched in Fig.4 ; the tap water is passed through a vacuum funnel where air bubbles are released and eliminated through the constant-level jar. In the same time the lateral connection of the funnel with the upper side of the permeameter allows the accumulated air to be evacuated. After air removing repeated measurements gave almost identical results.

When oedopermeameter was used for normal permeability determinations (Fig.4a) porous stones were replaced by perforated plates, the ways to get out water from the apparatus were enlarged and the upper piston was perforated. By these measures the hydraulic losses through the empty device were lowered down to only 1 mm water head, which is negligible for measurements. The oedopermeameter allows pressures in the range of 0 to 1 MPa to be applied.

When oedopermeameter was used for in-plane permeability determinations (Fig.4b) the orifices for water entrance and exit were provided at the lower part of the box, the piston had no perforations and was tightened by gaskets on lateral box walls.

The geotextile discs of 7-cm diameter were put together in bundles of 1.5 to 2 cm thickness and saturated with water, forming a sample, which was introduced in the oedopermeameter box and submitted to an initial pressure of 2 kPa. After water de-aeration the pressure was increased and the height H (cm) of sample was read by dial gauge. If the head loss (read by piezometers) is Δh, the time required to pass 1000 cm^3 of water through the sample is t (seconds), and the transversal area of sample is A (cm^2), the coefficient of permeability is given by :

$$k = \frac{1000\ H}{A \cdot \Delta h \cdot t} \quad (cm/s) \qquad (2)$$

In order to express the density state of geotextile in the same manner as for soils /7/ the volume V_{100} was used, corresponding to 100 g dry geotextile ; by this way the need to establish fibre density - which is doubtful especially for waste materials - is avoided. Also, knowing that permeability is proportional with the square of pore mean diameter, the volume V_{100} was plotted against $\sqrt{k}$ instead of k, thus obtaining a linear dependence (Fig.5 left side) under the form :

$$V_{100} = a + b\ \sqrt{k} \qquad (3)$$

By the same way the relation between pressure (higher than 20 kPa) and V_{100} was linearized (Fig.5 right side) under the form :

$$V_{100} = V_o - C_c\ lg\ p \qquad (4)$$

where C_c is the compression index of soil.

The dependence of permeability on applied pressure may be thus expressed as follows :

$$a + b\ \sqrt{k} = V_o - C_c\ lg\ p$$

or

$$\sqrt{k} = \frac{V_o - a - C_c\ lg\ p}{b} \qquad (5)$$

where all coefficients a, b, C_c and V_o can be experimentally determined by oedopermeameter tests. This relation is needed when earthworks including geotextiles are planned.

4 CONTAMINATION OF GEOTEXTILES

A very significant problem occurring when granular inverted filters are replaced by geotextiles is the permeability reduction during filtration process as a result of contamination. The term "contamination" is meant as the retention of a certain amount of soil particles between the fibres whereas "colmatation" results in the total impermeabilization of geotextiles.

The studies carried out by the authors showed that among Romanian geotextiles the most liable to contamina-

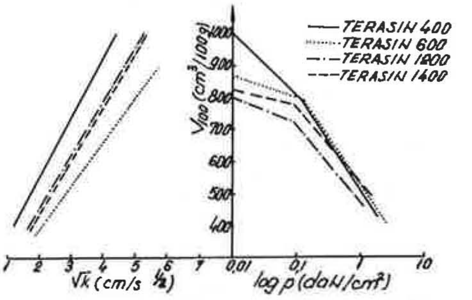

Fig.5. Relations between density, permeability and applied pressure on geotextiles.

tion are the loose unwoven materials like BIDIM (unimpregnated TERASIN, MADRIL) whereas denser types (NETESIN and especially impregnated TERASIN) are less sensitive /4,5, 8/.

The evolution of filtration process through granular filter/soil and geotextile/soil systems has been studied on different models.

The model presented in Fig.6 was intended to the

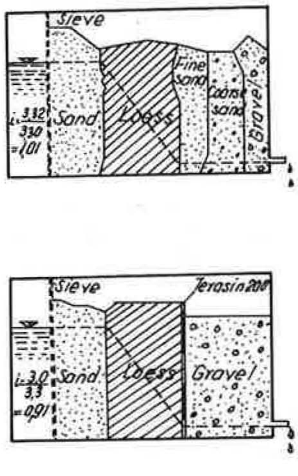

Fig.6. Model for studying geotextile efficiency.

study of filtration under low gradients. It is made of organic glass and divided in two parts by a perforated wall. In the left side water is maintained at a constant level and then reaches the filter/sand system after passing through sand and loess layers. In order to compare various draining systems the permeability was expressed by a global coefficient $\bar{k}$ deduced from Darcy's law and corresponding to a draining width b equal to 1 cm ; the upstream water height is H and the total discharge is Q :

$$\bar{k} = Q/(H\ b\ t\ i) \qquad (6)$$

The results of these tests are presented in Fig.7; they show that, on one side, the draining capacity of Romanian geotextiles manufactured from synthetic wastes is equivalent to that of foreign - made geotextiles or of granular filters and, on the other side, the contamination process is unimportant and it develops in all cases during 3 ... 4 days from the beginning of tests.

The filtration under hydraulic gradients higher than the unity was studied with the arrangement showed in Fig. 8a. The vertical water flow passed through a silty soil

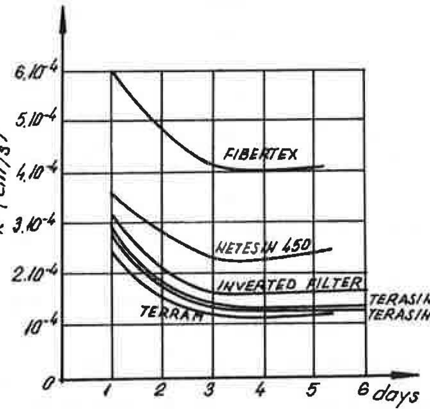

Fig.7. Variation of the coefficient of permeability for loess/geotextile and loess/inverted filter systems.

- from examined filters, none was contamined.

From these experiments it resulted also that only a small amount of soil passes through geotextiles (less than 20 % from particles in suspension) and this happens only as filtration begins ; later on the percentage decreases below 1 %.

5 A NEW COMPOSITE GEOTEXTILE DRAINING CARPET

The new prefab material recently realized in Romania consists of a gravel layer glued on a synthetic fabric 1-mm mesh placed between two sheets of NETESIN 300. Fig.9a shows a drain where this material has been employed and in Fig.9b the scale model used for studying the drainage capacity of the system is presented.

Experiments performed with this new drain showed that its efficiency is influenced by the nature of fibres which the geotextile covering the gravel fill is made from. If the geotextile contains less than 10 % natural fibres the permeability of prefabricated drains diminishes during the first 3 days of use, then it remains constant; some decontamination may also occur later on(Fig.10). If the geotextile contains up to 20 % natural fibre wastes the permeability slightly decreases during the first week of use. The influence of the nature of fibres is more significant in the case of laminary flow.

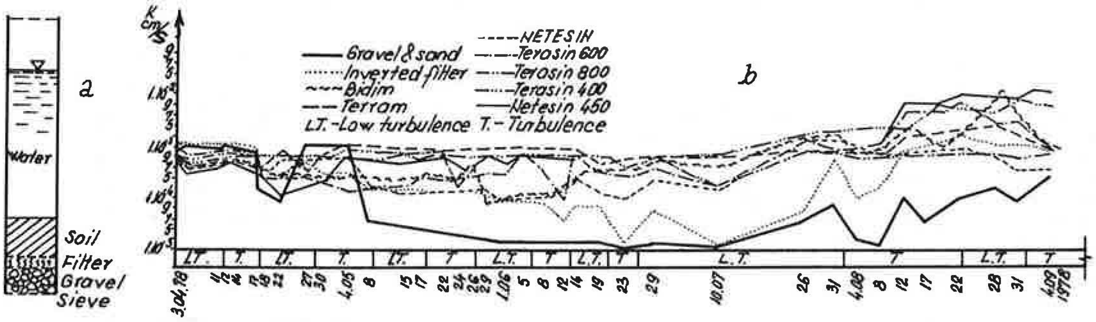

Fig.8. Filtration under high gradients.

layer (22 % clay, 53 % silt and 25 % sand fractions) then followed a variant of filtering system (classical, gravel or one of the geotextiles shown in Fig.8b).

For achieving a more realistic modelling, water was poured either directly on the soil layer (as a rainfall) or through a layer of synthetic geotextile filter (NETESIN).

The coefficient of permeability was determined under variable water head conditions. Results obtained from filtration tests carried out over a period of 6 months and represented in Fig.8b lead to following findings :

- the soil/geotextile draining system reduces the differences between the permeability coefficients of various geotextiles, and after a certain time the filtration curves get very close ;
- when water turbulence was high (during rainfalls) the permeability decreased, whereas when a filtering layer was interposed between water and soil, the permeability increased, i.e. a decontamination took place. During 1 to 3 months from test start there were sensible permeability variations ; the formation of a "natural inverted filter" may explain the stabilization of filtration process and even the further increase of permeability ;
- denser and thicker geotextiles (TERRAM, TERASIN 600 or 800) lead to a quicker stabilization of drainage flow than looser and thinner ones ;

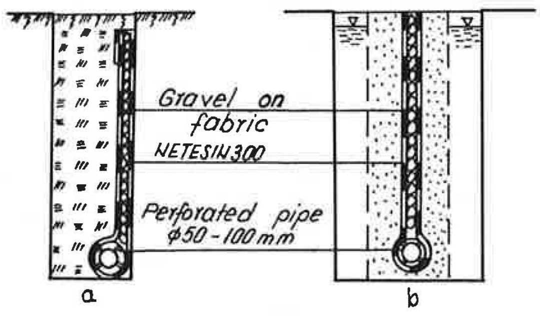

Fig.9. Drain with prefab gravel-geotextile carpet.

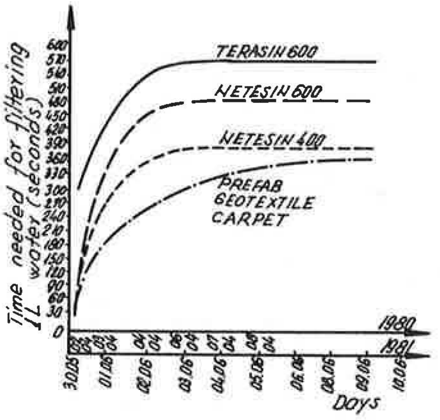

Fig.10. Results of contamination tests.

6 WORKS CARRIED OUT IN ROMANIA WITH GEOTEXTILES MADE OF WASTE MATERIALS

The first experiments were made in 1974 when protection layers and a transversal drain has been realized on a highway near the city of Iasi/9/ using NETESIN. The total area of geotextiles made from waste materials and used so far in Romania exceeds 2 mil. m^2 ; about a half of them served for draining works. Also slope protection railway, anticontaminant layers, and bank protections were executed ; they were experimented also on some asphaltic covers /10,11/.

The variation of water discharges collected by transversal drains has been recorded from 1976 on ; some variations have been observed due to rainfalls but no colmatation was reported (Fig.11). Thus during the fall of 1978 after a dry period discharges of drains 12-16 decreased towards minimum values, and after 15 hours of rain - fall the discharge grew up to almost maximum values.

7 CONCLUSIONS

The research carried out resulted in the following main findings :

- the microscopical study of geotextiles is very useful, as it allows the structural peculiarities to be outlined, the contamination effect and the presence of occluded air bubbles to be cleared up ;

- by capillary effects, geotextiles retain appreciable quantities of water, but they easy release them back when low suctions (of several dozens of cm water head) are applied ;

- in order to characterize the porous systems of geotextiles and of soils in contact with them, as well

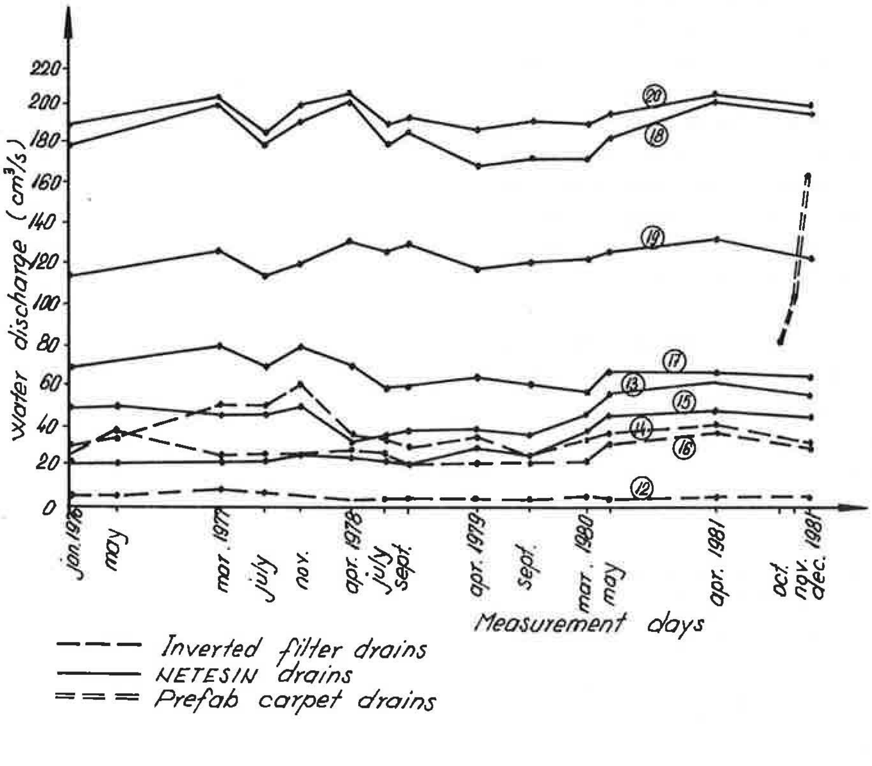

Fig.11. Variation of water discharge for transversal drains.

as the pore size distribution, it is useful to represent both particle size distribution and water retention curves on the same semilogarithmic diagram, thus obtaining a global feature of soil-geotextile systems ;

- the pore size distribution as determined by means of water retention curves is in good agreement with that observed by microscopic studies whereas the sieving of normalized sand shows smaller pore sizes than actual ones ;

- the unwoven geotextiles produced in Romania have practically the same structural and hydric properties as those manufactured abroad ;

- under hydraulic gradients as high as 0.5 to 1.0 a permeability decrease to about half the initial value occurs - this process has a duration of few days ;

- geotextiles are much more compressible than soils - from this reason the permeability of geotextiles is intensely influenced by overburden pressures exerted on them ;

- a correlation between pressure and permeability has been formulated ; it includes some experimental coefficients which may be determined by oedopermeameter tests ;

- the original oedopermeameter described in the Paper is provided with a water de-aeration device, which may be extended to ordinary permeameters for soils ;

- when hydraulic gradients are high, in the case of turbulent flow, the permeability coefficient of soil - synthetic geotextile systems is variable upon a certain time interval, then it approaches a steady value. Even in these conditions contamination of unwoven fibres does not occur, and moreover a decontamination effect was observed. The laminary flow through drains is influenced by the proportion of natural fibres in the composition of geotextiles.

- when unwoven filters made of synthetic wastes are used instead of classical inverted filters significant economical advantages are obtained : water discharge through geotextile drains remained practically unchanged after 6 years of operation.

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