KELLNER, L., BALLY, R. J. and MATEI, S.
Hydraulic Engineering Research Institute, Bucharest, Romania

Some Aspects Concerning Retaining Capacity of Geotextiles

Quelques aspects concernant la capacité de rétention des géotextiles

The paper deals with several aspects concerning the use of fabrics as filtering elements. A laboratory procedure by which the fabric capacity of retaining solid discharge may be determined is presented. The obtained results for the examined phenomenon allow the establishment of characteristic curves and indices. It is also emphasized the fact that defining this phenomenon on the basis of dimensional elements only is unsatisfactory,many of the geotextiles manifesting a susceptibility to retain fines due to the action of electrochemical forces. The intensity of these forces is strongly correlated to the chemical nature of the polymer of which the fabric is made and the mineralogical composition of the soil. For evaluating the geotextiles filters operation, criteria have been formulated establishing the domain or utilisation conditions, taking into account all the revealed aspects concerning the geotextiles capacity to retain the solid discharge. The stated criteria validity had been confirmed by tests on physical models.

L'article traite quelques aspects concernant l'utilisation des géotextiles comme éléments filtrants. On présente une méthodologie de laboratoire à l'aide de laquelle on peut déterminer la capacité des géotextiles de retenir le débit solide. Les données obtenues permettent d'établir des courbes et des indices caractéristiques au phénomène analysé. On remarque aussi qu'il ne suffit pas à définir ce phénomène exclusivement à base des éléments dimensionnels, de nombreuses géotextiles manifestant une susceptibilité à retenir les fines particules sous l'action des forces de nature électrochimique. L'intensité de ces forces est dans une corrélation étroite avec la nature chimique du polymère des géotextiles et la nature minéralogique du sol. Pour l'évaluation de la fonctionnalité des filtres géotextiles on a formulé des critères qui établissent le domaine ou les conditions d'utilisation, en tenant compte de tous les aspects relevés concernant la capacité des géotextiles de retenir le débit solide. La validité des critères énoncés a été confirmée par des vérifications sur des modèles physiques.

The use of geotextiles as filtrant or filtrant-drainant elements requires the knowledge of the characteristics to be considered in estimating their hydraulic and protective efficiency expressed by the fabrics permeability and their capacity to retain the solid discharge. It is of extreme importance to formulate certain judgements concerning the conditions of optimal operation and the evolution in time of geotextiles capacity, as filtrant or filtrant-drainant elements.

DETERMINATION OF GEOTEXTILES CAPACITY TO RETAIN THE SOLID DISCHARGE

In the Hydraulic Engineering Research Institute from Bucharest a special programme to determine geotextiles capacity of retaining the solid discharge was initiated. The test consists in the filtering of a soil-water suspension through a geotextile under a constant high of 10 cm of suspension column (fig.1). For the performance of tests a device of the dead-level permeameter type was used. The grained material from the permeameter as well as from the water supply tank is permanently maintained in suspension by rotating agitators.

Preliminary tests led to the following optimal parameters of testing:

- suspension concentration: 5%;
- grained material having a continuous grain size distribution from 0.002 mm to 2.0 mm
- filtering duration: 15 minutes.

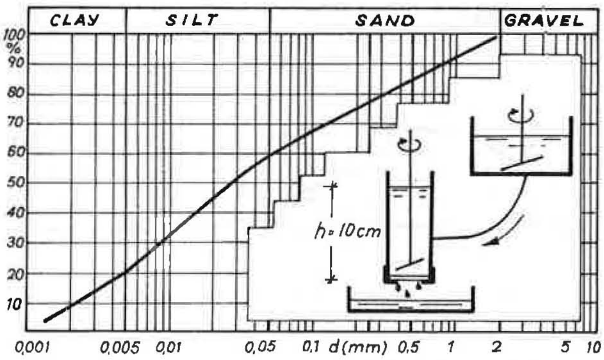

Fig.1. Testing conditions for the geotextiles capacity to retain the solid discharge

The values obtained by this test are: the grain size distribution and the solid mass quantity passed through the geotextile (P) remained on it (R) and remained in the geotextile (R_{in}). For the quantity remained on the geotextile and the one passed through it the methodology needs the complete collecting of the corresponding part of material,sedimentation and filtering of solid part,drying it to constant weight. The weights of each of these parts are then determined by weighing and the grain size distribution by usual sieving and hydrometer method.For the mass remained in the geotextile the use of indirect methods is accepted: the mass quantity is obtained by the difference between the weight of fabric sample dried at constant weight, before and after the test, and the grain-size distribution by the difference between the initial grain-size distribution of the material and the cumulated size distribution of the grains retained on and passed through. In this manner, the characteristic curves of retaining capacity for different fabrics may be represented in a semilogarithmic plot (fig.2).

OBTAINED RESULTS AND CHARACTERISTIC ELEMENTS

The tests performed on various types of woven and non-woven geotextiles: MADRIL, TERASIN, BIDIM, TERRAM, ALFA, made evident the fact that as far as fabric retaining capacity is concerned there are two different kinds of behaviour well characterized by their retaining capacity curves (fig.2).

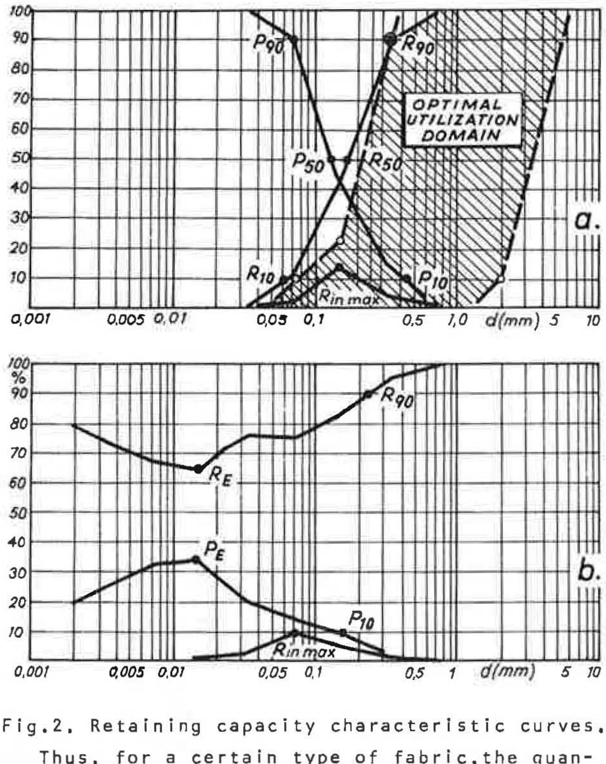

Fig.2. Retaining capacity characteristic curves.

Thus, for a certain type of fabric, the quantity of mass passed through increases as the particle size diminishes (fig.2.a). It is the case of geotextiles with large pores (non-woven) or openings (woven) which manifest a retaining capacity of mechanical nature towards the solid particles. For another group of fabrics the retaining capacity acts on the silt and clay particles, intensifying as the particles dimensions decrease (fig.2,b). As in 99% of the cases the pores dimensions are larger than that of the fractions for which the mechanical retention becomes possible, this phenomenon could be attributed to the electro-chemical forces action. This is the case for fabrics with small pores or openings that dimensionally create the conditions for the electrochemical forces action in the filtering of a soil suspension through the fabric. The tests performed up to now by the authors situate almost all examined non-woven geotextiles mechanically consolidated by needle punching in the last group.

The retaining capacity graphs may be used to define some specific values which by their nature could be considered retaining capacity dimensional indices for geotextiles.

Expressing the illustrative limits of the analysed phenomenon the following retaining capacity dimensional indices are proposed:

- the extreme dimensions of the soil particles that 90%, 50%, 10% remain on the geotextile (R_{90}, R_{50}, R_{10}) or pass through it (P_{90}, P_{50}, P_{10});
- the dimension of solid particles that in the greatest proportion are retained in the geotextile ($R_{in\ max}$);
- the dimension of solid particles from which the retention by electro-chemical forces probably begin to act (R_E).

Objective causes connected to errors that could be introduced by the manner and technique of testing, imposed as maximum and minimum dimensions of the soil particles passing through or remaining on the geotextiles those corresponding to 90% and 10% respectively.

The retaining capacity dimensional indices can equally characterize the woven and non-woven fabrics. Obviously the solid particles retention for woven fabrics being incompatible with their structure, the $R_{in\ max}$ index is missing and the remained on and passed ones are equal:

$$R_{90} = P_{10} \text{ and } R_{10} = P_{90}$$

The authors consider that the retaining capacity dimensional indices also provide informations concerning:

- the maximum dimensions of the non-woven geotextile pores and of the woven geotextile openings (R_{90});
- the evaluation of the domain of soil particles dimensions over which the geotextile performs its retaining capacity ($R_{90} - R_{10}$);
- the dimension of the solid particles susceptible to be retained in the fabric ($R_{in\ max}$);
- the geotextile susceptibility for clogging by retaining the solid particles on and in it due to electro-chemical forces (R_E);
- the degree of non-uniformity for non-woven fabrics pores or for woven fabrics openings considering the following proposed intervals:

$$\text{uniform} \quad 5 > R_{90}/R_{50} > 5 \quad \text{nonuniform}$$
$$15 > R_{90}/R_{10} > 15$$

REMARKS CONCERNING THE GEOTEXTILES SUSCEPTIBILITY TO RETAIN THE SOLID DISCHARGE

An orientation of studies concerning the manner in which fabrics perform their function of retaining the solid discharge is based on defining this function in relation with the particles dimensions and the fabric porosity characteristics (3, 6, 7, 9).

The results obtained from the testing on the geotextiles capacity to retain the solid discharge emphasized the fact that this phenomenon is far too complex to be exclusively defined by some dimensional elements: soil grain size and fabric porosity and pore dimensions (1).

For several reasons the characterization of fabric retaining capacity for solid particles by dimensional elements only is questionable:

- the dimensional values illustrating the soil grain size and the fabric porosity are obtained by indirect tests (the grain size hydrometer analysis and the method based on suction respectively) fact that give them a high degree of conventionality;

- the differing principles on which these values are determined make their comparison doubtful;

- the restrictive effect of a porous medium with wide specific surface is obviously more complex than that attributed to a mechanical process.

The above mentioned reasons suggested to the authors the examination of the geotextile and soil nature influence (chemical or mineralogical composition) over the intensity of the fine particles retention phenomenon.

The attention has been oriented towards the unexpected process of retaining particles finer than the fabric pores dimensions.

The experimental programme operated with four types of fabric produced in Romania: MADRIL M, MADRIL V, MADRIL P and TERASIN and four types of soil: caolin, loess, quartz sand and micaceous sand.

The characteristics of the experimentated geotextiles made of various polymers and having different structures are mentioned in table 1.

Table 1. Definition charcteristics of geotextiles used for the experimental programme.

geotextile	nature of the polymer	fibre characteristics (tex/mm)	technology	mass μ (g/m^2)	thickness T (cm)	porosity n (%)	percent distribution of pores O < 0.03 mm	O > 0.03 mm
MADRIL M	pp	0.66/60	needle-punched	520	0.57	89.9	0.3	99.7
MADRIL V	pp	1.99/100	needle-punched	560	0.59	89.6	0.2	99.8
MADRIL P	pes	0.44/60	needle-punched	470	0.42	91.6	0.3	99.7
TERASIN	mixt. pes,pna pp (waste)	—	needle-punched and chemically bonded	660	0.75	89.0	0.5	99.5

The soils, loess excepted, are unminerals their grain-size distribution being specified in figure 3. For the tests they have been used individually and in mixtures of two. The tests have been performed in conformity with the above expressed methodology for the determination of fabric capacity to retain the solid discharge.

In order to emphasize the intensity of the observed phenomenon the retaining capacity has been analysed for the material having particle dimensions smaller than 99% of geotextile pore (d < 0.03 mm).

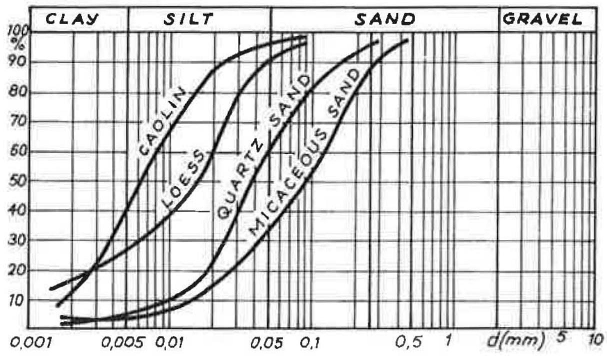

Fig.3. Grain-size distribution of the soil used in tests for the determination of the geotextiles susceptibility to retain fines.

The fabric susceptibility to retain particles smaller than the pore dimensions - Sg (0.03) - is expressed by the ratio between the quantity of particles smaller than 0.03 mm remained on the fabric - R (0.03) - and that having d < 0.03 mm from the initial soil - G (0.03)

$$Sg\ (0.03) = \frac{R\ (0.03)}{G\ (0.03)}\ 100\quad (\%)$$

The results obtained for the four types of soil and the four tested fabrics are mentioned in table 2.

Table 2. Geotextiles susceptibility to retain particles smaller than the pores dimensions.

geotextile \ soil	quartz-sand	micaceous-sand	caolin	loess
MADRIL M	91	53	72	94
MADRIL V	78	80	92	77
MADRIL D	87	92	88	92
TERASIN	74	79	87	84

The presented results allow the following findings:

- in all the cases the fabric susceptibility to retain particles smaller than the pore dimensions is obvious;

- the differences are present both in the behaviour of each of the soil types towards the fabric and in the behaviour of each fabric towards the corresponding soils, the difference between the maximum and minimum percentage of the retained material being for the same fabric between 5% and 41% and for the same soil between 17% and 39%.

- generally speaking the analysed susceptibility is greater for caolin and loess than for quartz and micaceous sands, the former ones being retained on an average of 85% and 87% respectively and the latter ones on an average of 76 % and 83% respectively.

These facts argue for the supposition that during the filtering process the fabric restrictive effect on the solid discharge cannot be expressed only by a retention of mechanical nature.
but also by the influence of some electrochemical forces action.

The intensity of this action is connected to the nature of the two media: soil and fabric.

The specific behaviour of each unimineral soil-fabric ensemble imply a more complex manifestation than in the case of mineral mixtures of two or more than two components.

The tests accomplished to point out this aspect have been performed on mixtures of two components from the four soils: quartz sand, siliceous sand, caolin, loess, the combinations in all cases being made for a weight ratio of 4/1; 1/1; 1/4.

The influence of the mixture on the fabric susceptibility to retain fines was expressed by the ratio between the susceptibility estimated by calculus and the one ascertained by tests.

Considering that the difference of ± 0.1 is included in the domain of possible errors that can be introduced by the determination technique it was accepted that the ratio from 0.9 to 1.1 emphasize that the behaviour is corresponding to the values computed in conformity with the dosage.

The ratio smaller than 0.9 indicate an accentuation of the analysed susceptibility and the ones higher than 1.1 its diminution.

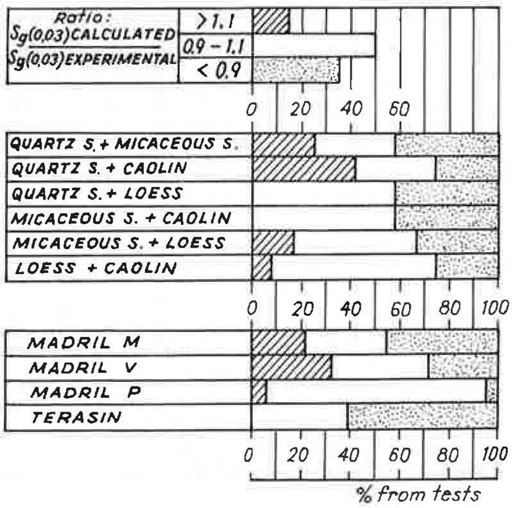

Fig.4. Soil mixtures influence on the geotextile susceptibility to retain solid discharge.

The obtained results (fig.4) leaded to the following:

- a general estimation resulting from the analysis of all the tests performed shows that the mineral mixture is able to influence the fabric susceptibility to retain the solid discharge; only 50% of the tests corresponds to the calculated values, the rest showing changes on both sides;

- the obtained results for each mineral mixture show in all cases an influence on the fabric retention of particles but with no important differentiations due to the dosage;

- irrespective of the mixture dosage and components each fabric introduces a specific behaviour; the ratio and the way in which the modifications act on the retaining capacity are seriously different depending on the polymer nature. An almost similar behaviour is to be noticed for the fabrics made of the same polymer (MADRIL M and MADRIL V).

The presented results concerning the fabric susceptibility to retain particles smaller than the pores dimensions underline the fact that during the filtering process the fabric capacity to retain the solid discharge is influenced by the soil mineralogical composition and the polymer chemical nature. Therefore the estimation of fabric behaviour as filtrant or filtrant-drainant element exclusively based on dimensional values of the two media is unsufficient.

CRITERIA FOR ESTABLISHING THE FABRICS OPTIMAL OPERATION CONDITIONS

The efficient operation of fabric filters is conditioned by a correct selection of the geotextiles in relation with the soil characteristics and the knowledge of the soil-fabric ensemble behaviour during the filtering process.

By analogy with the criteria for the grained filters several empirical rules (2, 4, 7) were proposed which define the hydraulic efficiency and hydrodynamic stability conditions depending on certain characteristic values of the two media: soil and fabric.

On the basis of the results obtained by tests concerning the fabric capacity to retain solid discharge, the authors establish the fabric optimal operation conditions using criteria that correlate the soil characteristic value (d) to the retaining capacity dimensional indices (5).

These criteria define the hydraulic efficiency and hydrodynamic stability condition, consenting that during the filtering process the fabric must allow the entire water amount to pass selectively restricting the solid particles transport as it is consented for the granular filters too.

For fabrics manifesting only a restrictive effect of mechanical nature the formulated criteria are as follows:

- for the stability condition:

  • the protected soil must contain maximum 10% fractions that pass through the fabric in a 90% ratio ($d_{10} \geqslant T_{90}$);

  • protected soil must contain minimum 10% particles larger than the pores or openings maximum dimension ($d_{90} \geqslant R_{90}$);

· protected soil must contain maximum 25% fractions corresponding to the maximum ones retained in the fabric ($d_{25} \geqslant R_{T\ max}$).

- for the permeability condition:

$$k_{fabric} \geqslant 2\ k_{soil}$$

The stated criteria define a "size distribution domain of optimal operation" specific for each fabric (fig.2.b).

For fabrics susceptible to retain fine particles by means of electrochemical forces the following criteria are formulated:

- concerning the condition of stability:
    · fractions smaller than 0.05 mm pass through the fabric with a ratio of maximum 25%;
- for the condition of permeability:

$$k_{fabric} > 5\ k_{soil}$$

· after checking up the fabric capacity to retain the solid discharge its permeability observes the condition:

$$k_{fabric\ (after\ testing)} \geqslant 5\ k_{soil}$$

For these fabrics the mentioned criteria do not actually restrict a granulometric domain of optimal operation their use being possible for all soils (sandy, silty and clayey soils).

The checking up of clogging susceptibility by retaining the fines is imposed.

In order to verify the valability of the proposed criteria, laboratory tests on physical models were performed observing the protection efficiency achieved by the fabric filter and its long term behaviour.

The models have been made of soil corresponding to the geotextile optimal utilization domain as well as of non corresponding one.

For emphasizing the aspects connected to the protection efficiency of fabric filters, samples have been subjected for short periods to flows up to i = 10 gradients.

The results obtained had been edifying. All the tests performed with optimal soil registered no grain drive through the fabric and no clogging phenomenon. For tests with nonconform soil the grain drive was present in all cases, sometimes having a progressive manifestation up to the complete passing of the soil sample.

The long term fabric filter behaviour was observed on models, during more than 700 days in which the flow had been maintained at constant gradient (i = 1).

The tests have been performed for filters of MADRIL M, MADRIL V, MADRIL P and TERASIN. For comparison a classical grained filter had been tested under the same conditions.

All models proved a good behaviour for fabric filters similar to that showed in figure 5 for MADRIL V 500.

All tests proved the existence of three stages marked by: the diminution of ensemble permeability due to the particle rearrangement on the moment of flow release; the increase of permeability during the period corresponding to the reverse natural filter formation on the soil-fabric contact area; the filtering process stabilization. In this last stage attained after about 300 days, the ensemble permeability lays between the extreme priorly attained values, being a little larger than the one achieved for the grained filter.

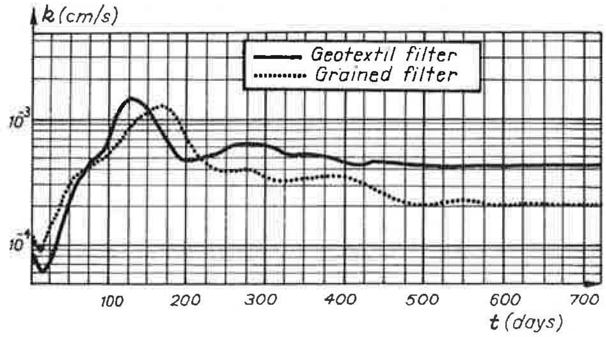

Fig.5. The long term behaviour of the geotextile filter MADRIL V 500.

Taking into consideration the obtained results it can be ascertained that in all cases the fabrics had a proper behaviour. Adding that the tests performed for emphasizing the protection efficiency leaded to the same quantitative results it is to be concluded that the fabric filtering operation evaluation on the basis of the above mentioned criteria can offer satisfactory results.

CONCLUSIONS

1. The geotextiles filtrant-drainant effect and their capacity to retain solid particles have been the object of a large experimental programme performed in the Hydraulic Engineering Research Institute.

2. The researches emphasized the necessity for grouping the geotextiles in two categories:

- geotextiles manifesting a diminution of the retaining capacity as the solid particles dimensions decrease. The activity of retaining the solid particles is predominantly of a mechanical nature;
- geotextiles manifesting an intensification of the retaining capacity as the solid particles dimensions decrease. In this case it is likely that the action of some electrochemical forces is added to the mechanical one.

3. The manifestation of a retaining capacity that cannot be expressed by the correspondence between the solid particles and the geotextiles pores dimensions had been particularly emphasized by experiments on soil with different mineral compositions and on geotextiles made of different polymers. The obtained results underline the influence exerted by the mineralogical nature of the soil and especially by the nature of the polymer the geotextile is made of over its capacity to retain particles having dimensions inferior to those of its pores.

4. The facts presented above (2;3) lead to a very interesting conclusion from the applicative point of view: the geotextiles capacity to retain the solid particles has to be experimen-

tally examined for each ensemble soil-geotextile as its evaluation on dimensional criteria (solid particles dimension and geotextiles pores dimension and porosity) only is not edifying.

5. The performed studies allowed the definition of certain characteristic indices regarding the geotextiles retaining capacity (characteristic diameters for the retained on and in the geotextile as well as for the one able of filtering through it). Taking into consideration these characteristic indices criteria are suggested for defining the conditions of optimal utilization of geotextiles working as filtrant elements particularly as substitutes of granular filters.

6. The validity of above mentioned criteria had been proved on laboratory models, long period models (more than 700 days) included, with positive results.

REFERENCES

(1) Bally, R.J., Kellner Lia, Dragomir, G., Matei Silvia, "On the geotextiles capacity of retaining the solid particles", Hidrotehnica (Bucharest, 11, 1981), 334; 339-341.

(2) Fayoux, D., "Filtration hydrodynamique des sols par des textiles", CR. Coll. Int. Sols. Textiles, vol.II (Paris, 1977), 329-332.

(3) Hoogendoorn, A.D., van de Meulen T., Preliminary investigation on clogging of fabrics, Delft hydraulics laboratory (no. 178/1977).

(4) Mc Keand, E., "The behaviour of non-woven fabric filters in sub-drainage applications", CR. Coll. Int. Sols Textiles - vol.II (Paris, 1977) 171-176.

(5) Kellner Lia, Bally, R.J., Matei Silvia., "Investigations on geotextile effectiveness as filter-drainage elements", Symposium: The utilisation of geotextiles in hydraulic engineering, road and railway construction and other fields of civil engineering (Bucharest, 1980), 153-161.

(6) Long, R., Healy, K., "Fabric filters on prefabricated under-drains", CR. Coll. Int. Sols. Textiles, vol.II (Paris, 1977)

(7) Masounave, J., Denis, R., Rollinx, A.L., "Prediction of hydraulics properties of synthetic non-woven fabrics used in geotechnical work", Canad. Geotechn. J.17 (4-1980) 517-525.

(8) Ogink, H.J.N., Investigation on the hydraulic characteristics of synthetic fabrics, Delft Hydraulic Laboratory (no. 146/1975).

(9) Shober, V., Teindtl, H., "Filter criteria for geotextiles. Design parameters in geotechnical engineering", VII ECSMFE, vol.II (Brighton, 1979) 121-129.