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SOME HYDRAULIC PROPERTIES OF GEOTEXTILE FILTERS BUILT INTO RIVER ENGINEERING STRUCTURES

QUELQUES PROPRIETES HYDRAULIQUES D'UN FILTRE GEOTEXTILE MIS EN OEUVRE DANS UN OUVRAGE EN RIVIERE

EINIGE HYDRAULISCHE EIGENSCHAFTEN EINES GEOTEXTIL-FILTERS IN EINEM FLUSSBAUWERK

This paper represents the result of systematic laboratory investigations of physical and hydraulic characteristics of geotextile filter that is used as a part of training structure - the revetment.

The investigations comprised the following:
- analyses of filtration coefficient with pure water and water loaded with suspended particles;
- influence of geotextile filter built into a revetment upon pressure oscillations in the porous medium in the background caused by wave motion in the laboratory channel, and
- change of geotextile filter structure under the influence of filtration particles of suspended load.

The obtained results clerify certain problems concerning the role of geotextile filter built into a revetment, so that they can be used in the process of designing.

In diesem Beitrag werden Ergebnisse systematischer Laboruntersuchungen einiger physikalischen Charakteristiken des Geotextilfilters vorgestellt, welches ein Element von Uferbefestigungen darstellt. Es wurden follgende Parameter untersucht: Filtrazionskoeffizient des Geotextilfilters unter Bedingungen des reinen sowie des mit dem Schwebstoff belasteten Wassers, Einfluss des Geotextilfilters auf die Druckveränderung im Hintergrund infolge der Wellenbewegung, Veränderung der Filterstruktur infolge der infiltrierten Schwebstoffpartikeln. Die erzielten Ergebnisse können zur Aufklarung der Rolle vom Filter in einer Uferbefestigung sowie bei der Projektierung dieser Bauten verwendet werden.

1. INTRODUCTORY REMARKS

The results presented in this paper represent part of the conclusions made after investigating the hydraulic parameters of geotextile filters used as one element of revetment. These investigations were carried out in laboratory conditions over a number of years using two model-devices specially constructed for this purpose:

- model for the investigation of the hydraulic characteristics of geotextile filters (model A), and
- model for investigating the effect of geotextile filters built into a revetment (model B).

These systematic investigations were to determine the basic hydraulic properties of the geotextile filters and its behaviour and effect once it becomes part of a revetment.

The scheme of the model (A) is given in Fig. (1) while that of model (B) is given in Fig. (2).

Device (A) was constructed in such a way that it is possible to at the same time (and under the same conditions) use it for investigating the value of the filtration coefficient in conditions of clean water and in conditions when the water is loaded with suspended particles, this both for the case when the water flows in the direction of the force of gravity as well as when it flows in the opposite direction. These experiments correspond to the conditions when the geotextile filter is not loaded too much (load of revetment does not effect the porosity) and when relatively coarse material is in the background of revetment.

The investigation of the geotextile filter built into the model of the revetment was done in the laboratory in a

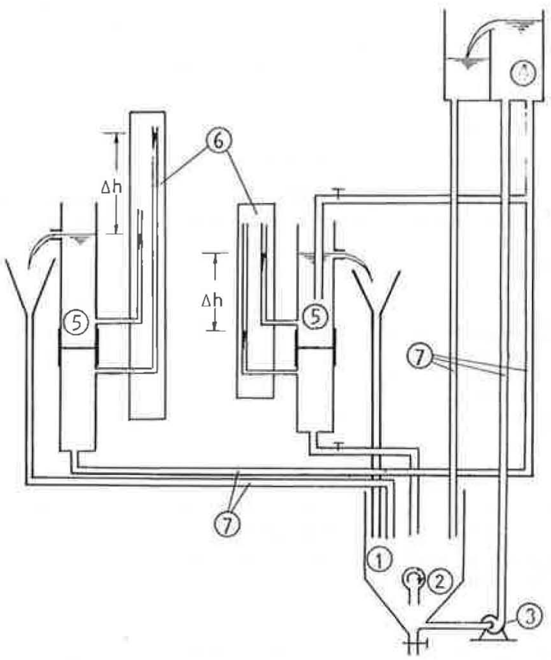

Fig. (1) Schematic presentation of the device (A) used for the investigation of the hydraulic properties of a geotextile filter. (1) - reservoir: (2) - mixer used for maintaining the suspension; (3) - circulation pump; (4) - reservoir for maintaining a constant flow; (5) - sampling cylinders; (6) - piesometer harp; (7) - plastic tubes.

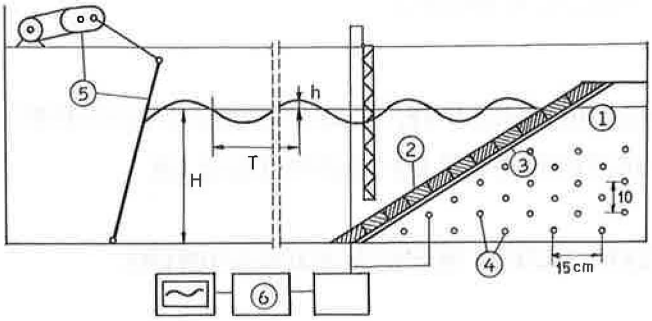

Fig. (2) SChematic presentation of device (B) used for investigating how the filter built into the model of the revetment effects the propagation of the pressure behind the structure under the influence of the oscillation of waves in the laboratory channel. (1) - porous medium - - background of the embankment; (2) - revetment of concrete blocks; (3) - geotextile filter under the revetment; (4) - piezometers; (5) - wave generator; (6) - electronic equipment for pressure recording.

15 m long channel with a cross section of 0.75×1.00 m. The oscillatory flow of water in a channel caused by a wave generator that can generate waves of different amplitudes and frequencies at different initial depths in the channel in which the experiments are done. Table (1) shows the alternatives that have been analyzed.

Table (1)

Depth of water	(cm)	30	40	50	60	70
Height of waves	(cm)	4 8 12	6 8 10	14 15 17	11 12 14	16 17 18
Wave period	(s)			1.25 1.70		

The background - porous medium consists of Danube sand whose grain size distribution is given in table (2).

Table (2)

Grain diameter (mm)	0.21	0.27	0.30	0.33	0.40	0.44	0.52	4.00
Distribution p (%)	10	20	30	50	75	80	90	100

A total of 37 piezometers were built into the model and their distribution is shown in Fig. (2). This distribution guaranteed the measurements of the changes of the pressure in the background as well as the interpolation of the results when required.

Wave motion characteristics in the channel were recorded using a capacitive probe connected to a recorder through an amplifier.

The oscillation of the pressures in the piezometers built into the background of an revetment was recorded using resistant membrane probes connected to the already mentioned recorder by means of an amplifier.

Model (A) was used to analyze the hydraulic properties of some types of geotextile filters that are often used in Yugoslavia when constructing training structures on rivers. This model was used to:

- analyze the filtration coefficient for the selected type of geotextile filter;
- determine how the gravity force effects the conditions of filtration through a filter;
- determine how the number of layers of filter effects the value of the filtration coefficient, and
- determine how the concentration of suspended particles in water effects the filtration coefficient.

Model (B) was used to investigate the effect of the filter built into the revetment under the condition of wave flow in the channel, in order to determine the following parameters:

- the effect of the geotextile filter on the pressure distribution in the background;
- changes in the grain size distribution of the soil in the background and the effects of the geotextile filter, and
- changes in the structure of the geotextile filter exposed to the effect of wave motion of water loaded with suspended particles.

These analysis were done for a relatively large number of alternatives whose basic parameters are presented in Table (1).

2. ANALYSIS OF THE FILTRATION COEFFICIENT OF A GEOTEXTILE FILTER

The investigations of the filtration coefficient of a geotextile filter in different filtration conditions (single-layer or multiple layer filter in contact with clean water and with water loaded with suspended sediment particles; the flow direction in a relation to the direction of the gravity force, etc., were done on model (A) given in Fig. (1)).

According to the results of this analysis (see Fig. 3), the value to the filtration coefficient in conditions of

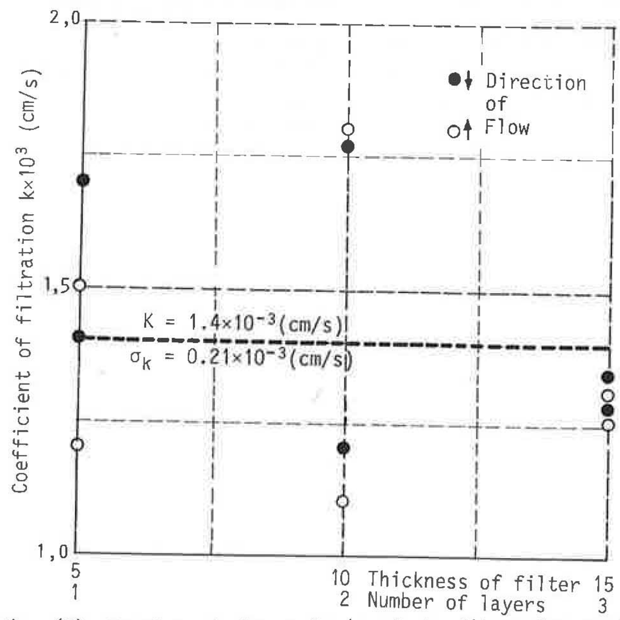

Fig. (3) Results of the analysis of the filtration coefficient for the selected geotextile and number of layers.

clean water, for the investigated type of filter, equals around 1.40×10^{-3} (cm/s). (In the previous investigations (1) the analysis was done for a more porous type of geotextile whose filtration coefficient equaled 3.5×10^{-3} (cm/s)).

The number of filter layers does not effect the value of the filtration coefficient so that any doubts about any air being left inside between the layers or about any other occurences that could be the result of the connecting of layers is thus excluded. This conclusion is in accordance with obtained results (1). It has to be underlined that the obtained results correspond to the geotextile without the surface protection and without porous medium in the background.

An analysis of how the direction of the flow influences the filtration coefficient (flow in the direction of the force of gravity and opposite) showed that there is no influence when determining the filtration coefficient in the flow of clean water.

However, suspended particles in water have quite an influence on both the change of velocity of filtration (see Fig. 4) and on the value of the filtration coefficient (see Fig. 5) in time.

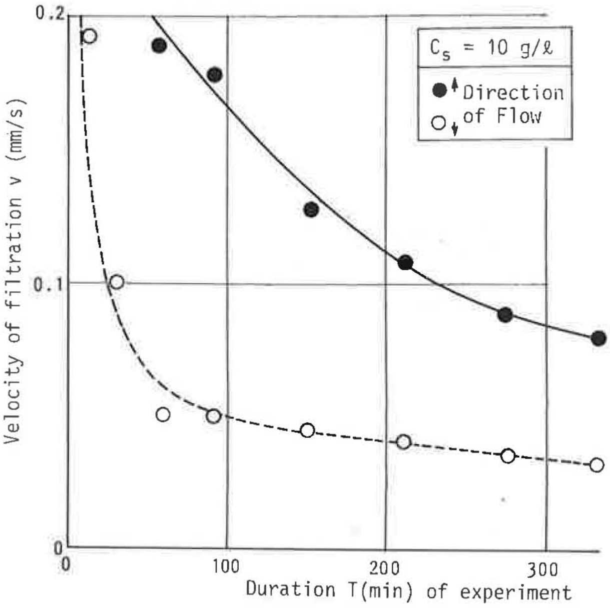

Fig. (4) Results of the analysis of the velocity of filtration with clean water: (v)- velocity of filtration (mm/s); (T)- duration of experiments (min); (C_S)- concentration of the suspension (g/1).

This phenomenon can be explained by the formation of a clogging layer on the surface of the filter as well as by a somewhat greater infiltration of the particles into the structure of the geotextile itself. In this specific case, the intensive reduction of the permeability of the geotextile lasts around 3 hours after which it reaches an approximately constant value.

If the water flows from the bottom in the upward direction, then the reduction of the velocity infiltration is less intensive, while the value of the velocity of infiltration is greater in the entire scope of investigation.

Similar conclusions can also be brought when analyzing the results given in Fig. (5): the values of the filtration coefficient of the same geotextile are smaller if the water flow has the same direction as the force of gravity. The values of the filtration coefficient after a certain amount of time (around 3 hours) reach a constant value.

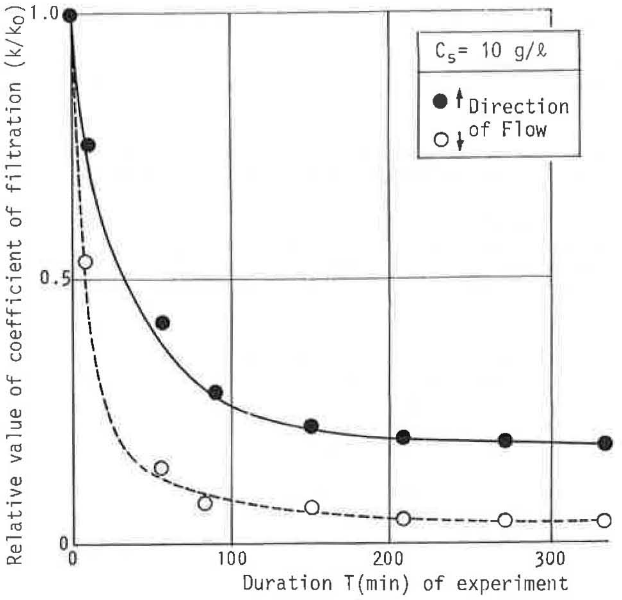

Fig. (5) Results of the analysis of the changes in the value of the filtration coefficient in time, for a certain concentration of suspended sediment. (k)- filtration coefficient (mm/s); (k_o) – initial value of the filtration coefficient (mm/s); (T)- duration of the experiment (min)

The value of the filtration coefficient for the same concentration of suspended sediment in water (C_s=10 g/1)

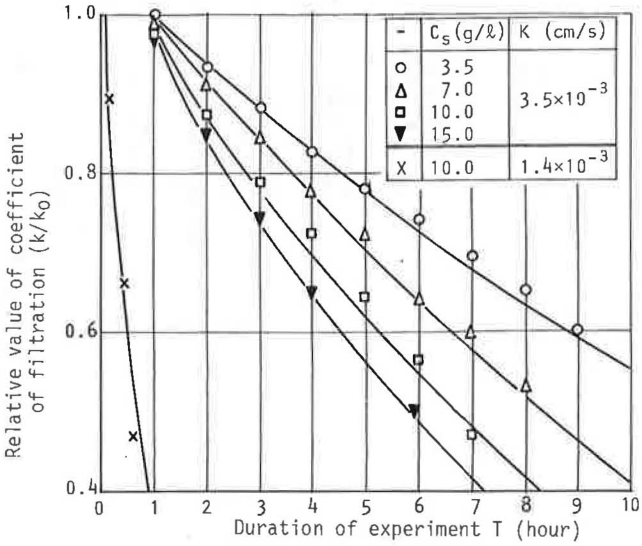

Fig. (6) Results of the analysis of the changes in the value of the filtration coefficient as a function of time for different types of geotextiles and different concentrations of suspended sediment decreases much faster when the geotextile whose average filtration coefficient is $k = 1.40\ 10^{-3}$(cm/s) is used then in the case of the geotextile when $k=3.5\ 10^{-3}$(cm/s).

The conclusions based on these analyses are important for the designers of revetment with built in geotextile filters as the significant reduction of the value of the filtration coefficient can result in the occurence of pressures in the background if water flows from the background into the watercourse.

Fig. (6) shows both the results obtained in the course of these investigations as well as those of earlier experiments (1).

3. ANALYSIS OF EFFECTS OF REVETMENT WITH GEOTEXTILE FILTER UPON THE POROUS MEDIUM IN THE BACKGROUND

A certain number of experiments that were part of these investigations were done to analyse how the geotextile filter built into a revetment model effects the oscillations of pressures in the porous medium in the background.

The consequences of the wave motion provoked in the channel (of already known characteristics) were registered in the background of the revetment model using a system of piezometers in the manner already described in the introductory part of this paper.

The results of measured pressure oscillations at all the measuring points have been presented in Fig. (7).

a consequence of the position of the measuring point in relation to the limits of the wave attenuation after the wave hits the revetment.

The purpose of the above analysis was to determine whether there is a marked tendency towards the changes in the pressures as the measuring points are more distant from the revetment.

In order to define the influence of the different characteristics of an incident wave, series of points that are characteristic for the analysis of the influence of certain parameters were selected.

Fig. (8) shows the results of the measurements of pressure oscillations in piezometers at the same level and along the length of the model ($\Delta H=0.6\ H$). The amplitude of the incident wave (h) was varied for a certain depth of water in the channel (H) and for certain wave period (T).

The diagram in Fig. (8) shows that the absolute value of the incident wave does not significantly effect the pressure oscillations in the background, i.e. that the process is linear.

The analysis of how the period of an incident wave influences the pressure oscillations in the background has been given in Fig. (9) based on the available data on the pressures registered in piezometers in the same horizontal plane. The waves generated were with periods of T=1.25 s and T=1.70 s and with amplitudes h=10 and 14 cm.

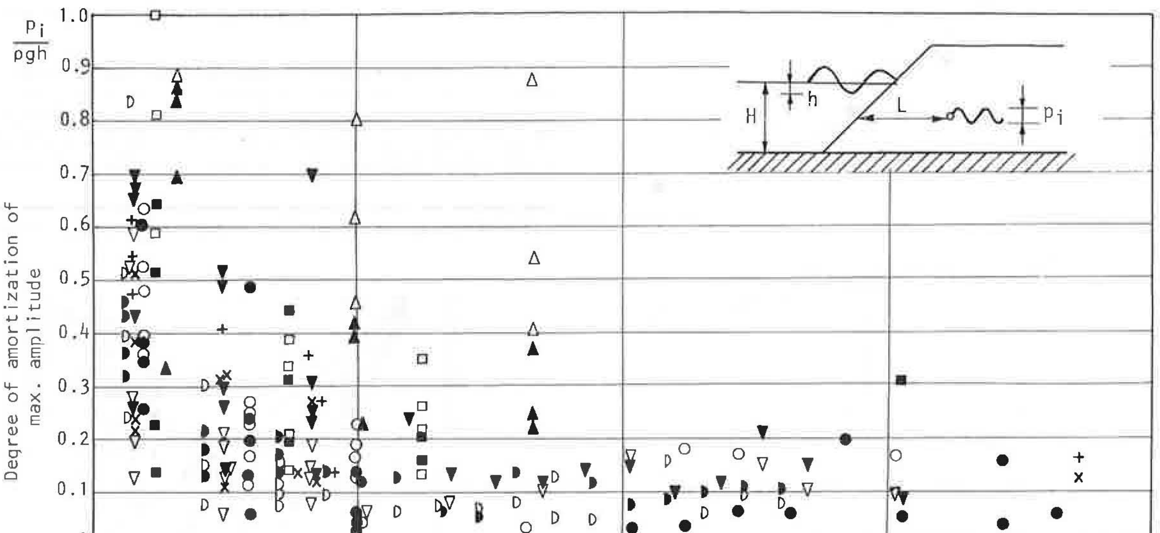

Fig. (7) Pressure oscillations in the background depending on the relative position of the measuring point. (p)- max. amplitude of the oscillation in the piezometer; (h)- amplitude of the waves in the channel; (H)- depth of water in channel; (L)- horizontal distance of the piezometer from the revetment; (i)- mark denoting the piezometer; (ρ)- fluid density; (g)- gravity constant. The denotations of certain points refer to different experimental alternatives, based on the data given in table (1)

The above leads to the conclusions that there is a marked tendency towards a significant reduction of the pressure oscillations caused by wave motion as the measuring point gets to be further and further away from the revetment.

The deviation of some experimental points from the centre of a system of points on the diagram given in Fig. (7) is

Based on the data given in Fig. (9), it can be concluded that the incident waves whose period of oscillation is smaller cause oscillations with an uniform decrement of amortization. If however the periods of oscillation are greater, the oscillations that occur are nonuniform.

It can therefore be concluded that when the periods are smaller the amplitudes of the pressure oscillations in the background are greater, and vice versa. These conclusions can probably be explained by the influence of the reflected waves which in the case of greater periods of the incident wave "have enough time" to influence the absolute values of the oscillations in the measuring points in the background.

The influences presented within the scope of the analysis performed so far are actually a result of the joint effect of both the effect lining of concrete blocks and of the geotextile filter. In order to differentiate between the effect of the filter and that of the lining, some

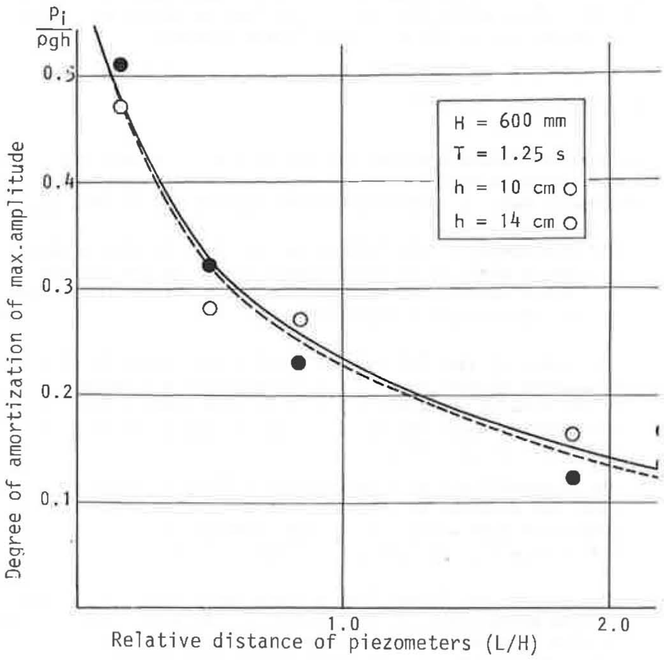

Fig. (8) Influence of the amplitude of an incident wave on the pressure oscillations in the background of revetment.

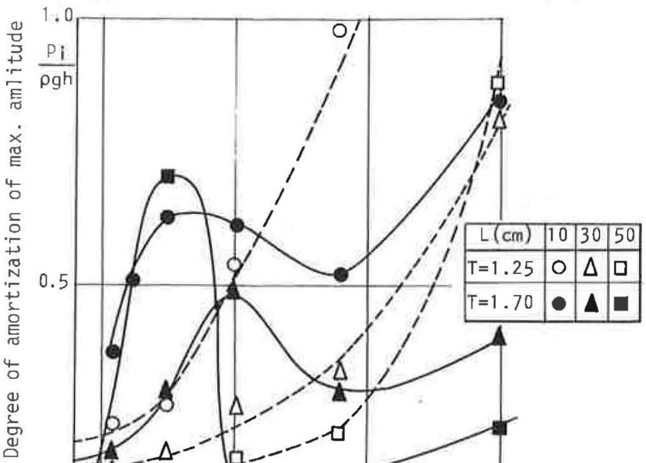

Fig. (9) Influence of the period of an incident wave on the pressure oscillations in the background

experiments were done without the lining. (It was not possible to do any experiments without the filter because of the washing away of soil particles from the background).

The results of this analysis have been presented in Fig. (10) and it is possible to based on these results conclude that the lining disperses the greater part of the energy of the incident wave so that the pressure oscillations in the background are quite a lot smaller then when there is no revetment. The remainder of energy is partly destroyed by the geotextile filter and partly by the porous medium in the background which as a result undergoes certain changes in its structure. Therefore, the role of a geotextile filter as part of the revetment is not as big from the point of view of the dissipation of energy.

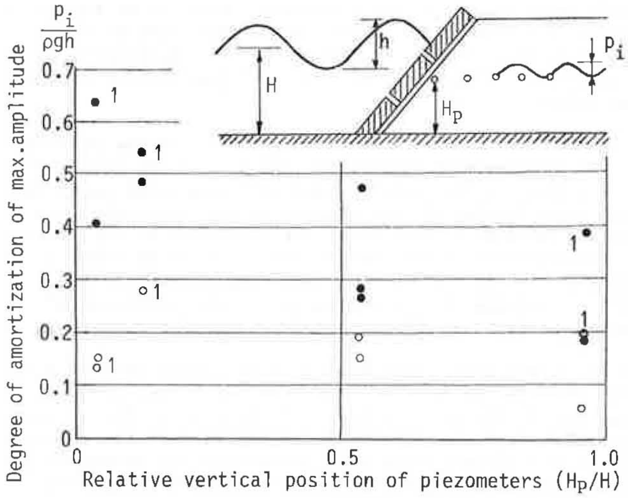

Fig. (10) Analysis of the influence of the lining of a revetment on the damping of the pressure oscillations in the background

The same device (model B) was also used to do a number of experiments with water loaded with suspended particles whose grain size distribution is presented in Fig. (11). This was done to determine the changes in the structure of the filter and in the structure of the soil behind the filter.

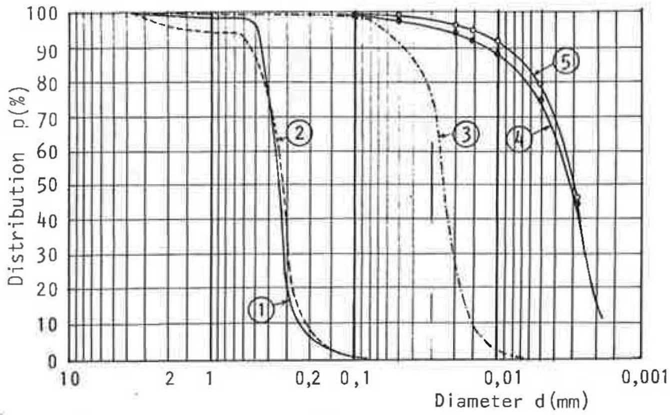

Fig. (11) Grain size distribution curves. (1)- curve of the soil example taken from the background; (2)- curve of the soil example directly under the filter; (3)- curve of the suspended particles; (4)- curve of the particles retained in the filter layer facing the water; (5)- curve of the particles in the part of the filter facing the background.

When doing these experiments, the concentration of the suspension varied between C_s=5.0-20.0 g/1. The characteristics of the wave motion were kept the same as in the experiments with clean water.

In order to determine the influence of the geotextile filter on the changes in the grain size distribution of the soil in the background of the revetment, an analysis was done of the soil samples taken directly from under the filter and from deep in the background. The grain size distribution of these samples has been presented in Fig. (11).

Fig. (11) shows that the changes in the grain size distribution directly behind the filter are relatively small and consist of the following: there is an increased amount of finer grains which can be explained by the penetration of the finer grains from the suspension through the filter and into the soil immediately behind the filter.

This conclusion is based on the analysis of the changes in the structure of the filter exposed to the action of wave motion in the water loaded with suspended particles. The investigation of the changes in the structure of a filter was done in two ways: one consisted of the microscopic analysis of the filter structure using samples taken after the experiments were completed while the other consisted of the separation of the infiltrated particles from the filter sample using ultrasonics.

Based on the grain size distribution curves presented in Fig. (11) it can be concluded that the larger grains remained in the surface layer of the filter. The finest particles from the suspension passed through the filter and as has already been said influenced the change of the grain size distribution of the soil in the background, immediately under the filter.

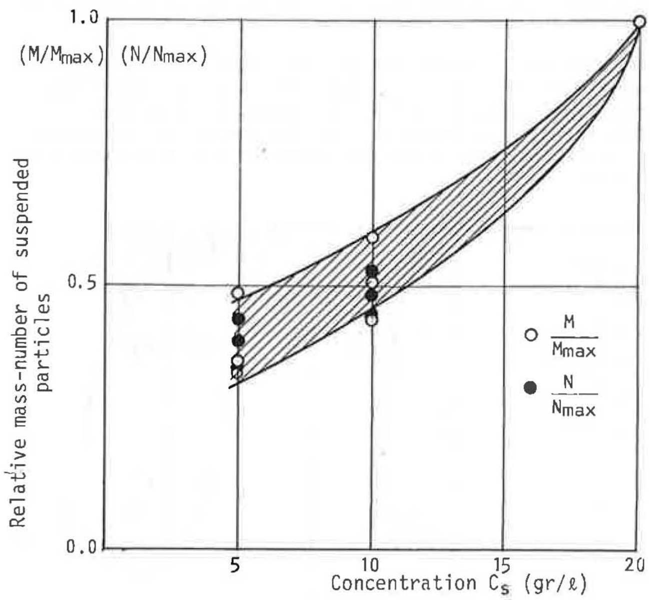

Fig. (12) Concentration of the infiltrated sediment particles expressed through the mass (M) and number of particles (N)

The amount of material that had infiltrated was determined after it was separated from the filter samples using ultrasonic.

The results obtained using both methods have been presented together in Fig. (12). For the sake of comparison, the results have been presented through the relative mass, that is through the relative number of particles, depending on the concentration of the suspension that was analyzed.

The above figure shows that both methods can be used succesfully for performing analysis of this type, although it should be mentioned that the method based on the use of ultrasonics has a certain adventage as it somewhat simpler. When it is more important to determine the grain size distribution of the infiltrated particles then the procedure with the microscope has an adventage since ultrasonic can break down the larger grains.

4. CONCLUDING REMARKS

Laboratory investigations of the hydraulic characteristics of geotextile filters built into the model of a revetment made of concrete blocks showed the following:

- the thickness of the filter layer, that is the number of layers when it is investigated without the effect of lining and porous medium, does not effect the value of the infiltration coefficient;
- the value of the filtration coefficient depends on the direction of the water flow loaded with a suspension: it is greater when the flow is in the upward direction and smaller when the water flows in the direction of the force of gravity;
- the permeability of a geotextile filter is reduced in time and depends on the degree of concentration of the suspended particles and on the initial value of the filtration coefficient of the filter, and
- the geotextile filter has a relatively small influence on the dispersion of the energy of the waves propagated to the background, this when compared with the influence of the lining itself.

The problem of a geotextile filter role within the revetment is very complex. Many quastions relating to a geotextile filter effects are not solved. This paper gives the answer to some of them, according to the knowledge of the authors.

5. REFERENCES

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