# LONG-TERM EXPERIENCE WITH THE USE OF SYNTHETIC FILTER FABRICS IN COASTAL ENGINEERING

by

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## ABSTRACT

Various types of synthetic filter fabrics are available for geotechnical applications. Especially in the field of coastal engineering a lot of experiences are generally known. Unfortunately technical recommendations and testing regulations for specific implimentations of geotextiles are not generally available and some actual examples of damage of coastal structures urgently require investigations on long-term resistance. A research program oriented towards the development of guidelines for testing geotextiles, the development of filtration rules and the clarification of long-term resistance of fabrics was carried out. This paper deals with testing procedures associatied with the estimation of the opening size and the permeability to water of fabrics. Results of investigations on long-term resistance are described and filtration rules for selecting a fabric according to the special requirements of the application are given.

## INTRODUCTION

Fore more than 10 years the use of synthetic filter fabrics in various types is a standard in coastal engineering works at the North sea coast.

We can distinguish the following applications to filter fabrics:

- as a filter-layer in revetments of seadikes and shore lines

- as a filter- and separation-layer for the foundation of groins and breakwaters
- as a flexible filter-layer for the bottom protection against scouring for example at tidal- and stormsurge-barriers and when closing a dike
- as sand filled bags or tubes as construction elements of groins and embankments.

Designing coastal structures, a synthetic filter fabric almost is represented only by a "synthetic filter fabric" named line (Fig. 1). At first this designation seems to be without problems but when selecting a suitable fabric for a special application the engineer has to recognize that there are a lot of conditions to be considered. He has to notice that various types of synthetic filter fabrics (woven, non-woven and combinations) are offered, produced of different polymers.

REVETMENT OF A SEADIKE WITHOUT FORELAND
(NORTHFRISIAN COAST)

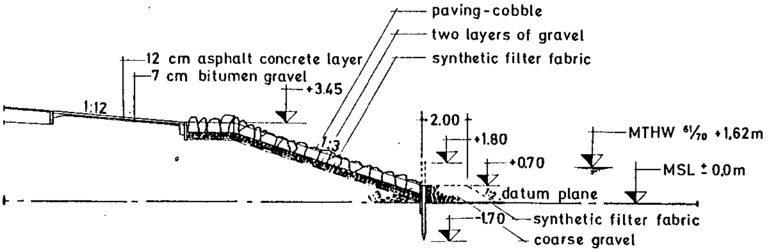
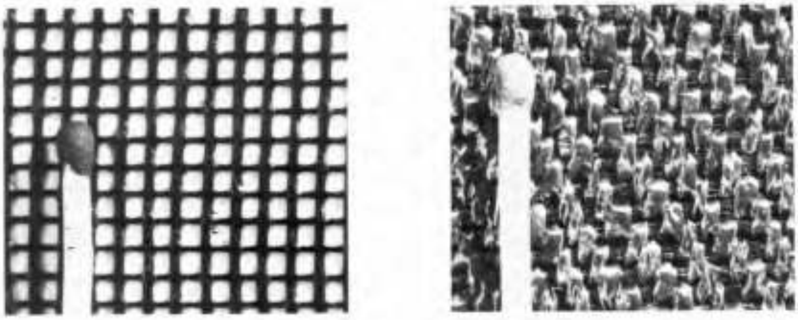


Fig. 1

TYPES OF FABRICS

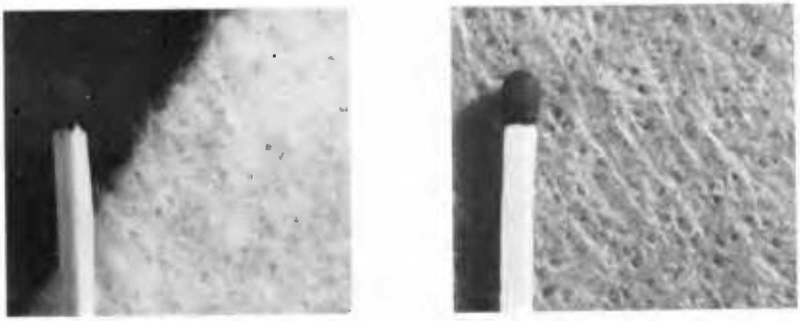
Of the variety of offered filter fabrics Fig. 2 only gives an impression by showing some of the most important kinds of woven and non-woven fabrics.



mesh netting

tape fabric

woven fabrics



fibre fabric

spun fabric

non-woven fabric

Fig. 2
Different kinds of geotextiles

The properties of fabrics are very different, influenced by the polymer properties and by the manufacturing process. For woven fabrics for example we have to distinguish the kinds of threads (multi-filament, mono-filament, tape threads), the kind of woving, the used polymer and the finish (e.g. PVC-coating). Non-woven fabrics also are produced by different polymers and we have to distinguish the method to obtain the cohesion of the fibres or filaments.

## THE GIVEN SITUATION IN USING FILTER FABRICS

For dimensioning and selecting a fabric a comparison of product datas and the requirements of the buildings, given by dimensioning rules or other proved standard values, is necessary. If there are two or more fabrics performing the requirements - a comparability of the testing methods is provided - a selection can consider economical aspects.

Unfortunately there exists a lot of different testing methods used by the manufactors to estimate the properties of the fabrics, so that the product datas of different fabrics are not comparable in many cases. Therefore an optimal selection of a fabric is very difficult and sometimes impossible.

It is an additional difficulty too, that there are no sufficient technical recommondations up to now to select a fabric according to the special requirements of the application. Therefore it doesn't wonder, that the present situation in the extensive use of woven and non-woven fabrics is characterized by a selction based on local experiences or on the costs per square meter.

Up to now there was no serious doubt about a sufficient long-term resistance of the synthetic fabrics covered by soil materials and protected against ultra-violet irradation. But actual examples of damage of coastal structures urgently require investigations to estimate the long-term resistance of fabrics, especially in comparison to the time of use of the structures (30 to 50 years).

## RESEARCH PROGRAM

The specified uncertainties in the use of synthetic filter fabrics lead to a special research program carried out at the FRANZIUS-INSTITUT FOR HYDRAULIC RESEARCH AND COASTAL ENGINEERING OF THE UNIVERSITY OF HANNOVER.

The investigation program consists of three parts:

1. extensive questionnaires were sent to the coastal engineering authorities to evaluate the experience in the use of the synthetic filter fabrics.

2. testing methods were development to estimate the filtration properties of fabrics.
3. various filter fabrics being in function for many years were diged out of coastal struktures.

From this investigations the following results can be presented:

## TESTING METHODS

To estimate the filtration properties of fabrics the developed testing methods allowed the determination of the effective opening size and the permeability as a function of superimposed load. The testing methods can shortly be described as follows:

To estimate the effective opening size we used a wet sieving with a defined testing sand. In the test, the fabric has to operate as a sieve (Fig. 3). The complete testing equipment for the wet sieving shows Fig. 4.

Fig. 3
Placing of the fabric for sieving operation

A grain-size analysis of the retained and the passing material leads to the effective opening size as a essential filtration parameter by a fixed evaluation method ( 4 ).

For testing the permeability of the filter fabrics we used a permeability test with constant hydrostatic head, generated by two overflow reservoirs, as proposed by BOURDILLON (1).

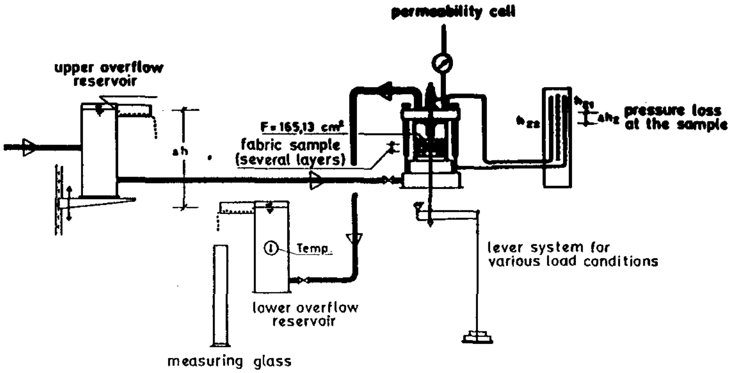
Fig. 4
Testing equipment for the estimation
of the effective opening size of geotextiles

Fig. 5 shows the test lay out. In the permeability cell a sample of several layers of the fabric is placed and after measuring the flow, the difference in piezometric level, the water temperature and the settlement of the sample a DARCY-coefficient can be determined. Repeating this procedure for various superimposed loads the permeability as another essential filtration parameter can be given as a function of load conditions.

This two tests may be like a standard for testing the filtration properties of synthetic filter fabrics. Only in special cases or for testing woven fabrics an additional test can be carried out, testing the system of fabric and original soil material. In cases of testing non-woven fabrics in combination with soil material it has to be considered that the testing conditions in the laboratory are very different to natural conditions. This is a result of field investigations on coastal structures. It can be seen that in non-woven fabrics-diged out of coastal structures - the incorporation of soil material is a multiple in nature than in a comparatively short laboratory test.

## FIELD INVESTIGATIONS

The field investigations on coastal structures mentioned before were the most important part of the research program.



EQUIPMENT FOR WATER PERMEABILITY TEST

Fig. 5

At 13 locations at the Northsea coast of the German Bight sampling operations were carried out and samples of 39 fabrics were taken.

16 samples were diged out of revetments of seadikes and 23 samples of woven fabrics were taken from sandbags and sand filled tubes.

Fig. 6 shows the revetment of the seadike without foreland at the Dithmarscher Bight at the Northfrisian coast and Fig. 7 gives an impression of the sampling operation at this location and in Fig. 8 a non-woven fabric is shown after removing the cover layers of the revetment.

The photographs in Fig. 9 and Fig. 10 give an example of the application of sand filled tubes. First as small dams in land reclamation fields in the tidal flats in front of the seadikes (Fig. 9) and second as stabilizing elements in a beach feeding area (Fig. 10).

From the sandbags and sandfilled tubes two different samples were taken, one of the weathered upper side and one of the

Fig. 6
Seadike at the Dithmarscher Bight at the Northfrisian coast

Fig. 7
Digging out a fabric

Fig. 8
Non-woven fabric after removing the cover layers

Fig. 9
Sand filled tube in a land reclamation field

Fig. 10

Sand filled tube in a beach feeding area

protected bottom side. By this it is possible to calculate the influence of weathering on the long-term resistance of the fabrics.

For fabric samples diged out of revetments the following individual investigations were carried out:

1. Condition and changing of the profile of the revetment
2. Condition of the fabric
3. Testing the tensile strength
4. Testing the filtration properties
5. Testing the fabric weight and soil content
6. Grain-size analysis and permeability test of the subsoil

For fabric samples of sand bags and sand filled tubes the research program is reduced to the following individual investigations:

1. Condition of the fabric
2. Testing the tensile strength
3. Estimation of effective opening size
4. Grain-size analysis of packed soil.

Essential results of the investigations of the seadike revetment are the registrated extensive filling of the coarse-layers with sand and mud particles and the considerable incorporation of soil in the non-woven fabrics. Caused by the filling of the coarse-layers with sand and mud, shown by Fig. 11, the boundary layer of fabric and subsoil was protected against dynamic wave attack.

Fig. 11

Coarse layers filled up with sand and mud particles

This situation also gave a stability in revetment sections with fabrics of too large opening size according to actual knowledge.

The extensive incorporation of soil in the non-woven fabrics lead to the assumption as mentioned before to doubt about the similarity to nature of laboratory test with non-woven fabrics and soil. Fig. 12 gives an example of an non-woven fabric with an incorporation rate of about 9000 grams per squaremeter by a fabric weigth of about 1000 grams per squaremeter.

Additional investigations lead to the perception that the sand and mud particles in the coarse-layers mostly came from the seaside of the construction and not from the bottom side. Some significant profile changes with a flater slope of the revetment were perhaps caused by soil-liquefaction under wave impact but certainly not by a washout through the filter-fabrics.

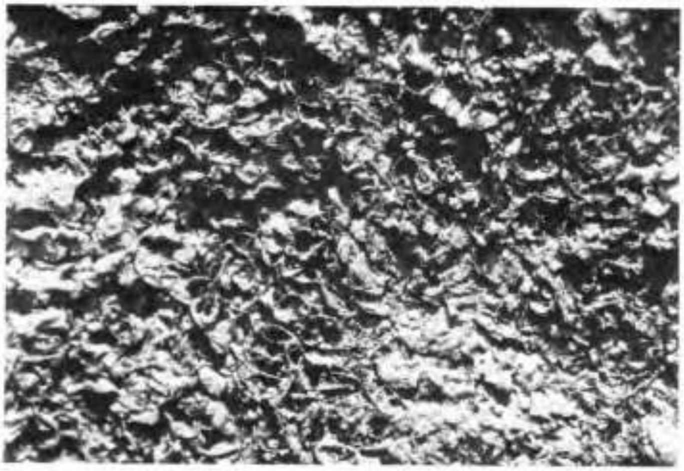


Fig. 12

Non-woven fabric filled up with sand and mud particles

## RESULTS ON LONG-TERM RESISTANCE

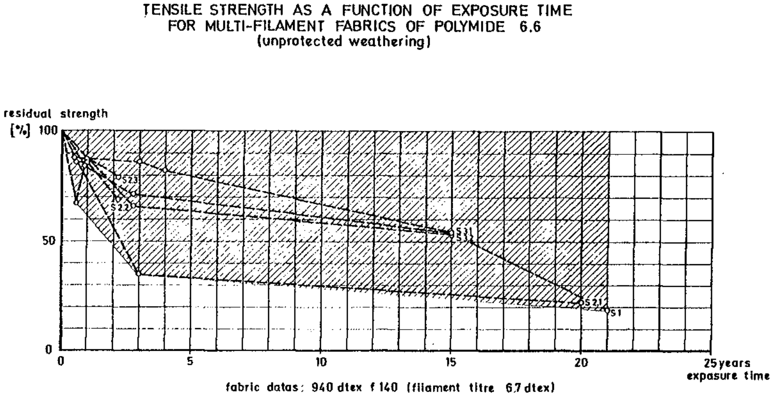
A usual method to give some informations about the long-term resistance of synthetics is a comparison of tensile strength of the new and of the aged material. The strength testing procedure used corresponds to the conventional textile strip test like the German standard (DIN 53857).

In the following some examples of the results of the investigations about long-term resistance of the synthetic filter fabrics are presented.

In Fig. 13 the relative residual strength determined for different fabrics of nylon (PA 6.6) as a function of exposure time by unprotected weathering is shown. The minimum value of residual strength is about 20 percent after an exposure time of 20 years. By protection against ultraviolet irradiation, the residual strength decreased only to values of about 70 percent after an exposure time of 20 years (Fig. 14).

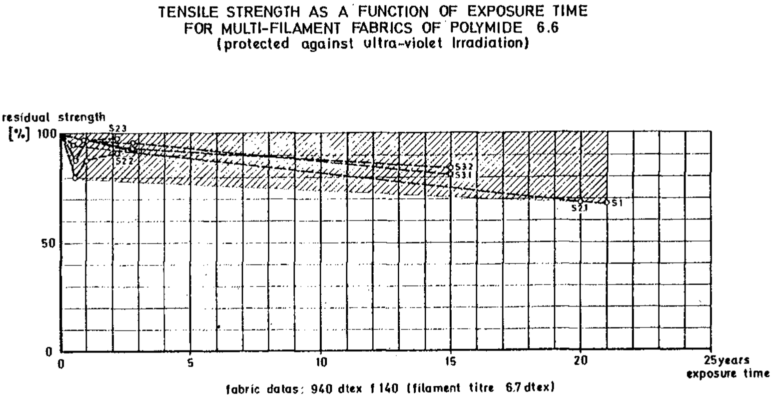
The next examples give an impression of the long-term resistance of all fabrics examined in the research program. For each of the base material of the fabrics average values of residual strength were determined.

Fig. 15 shows these average values for fabrics by unprotected weathering. It can be seen that the residual strength



TENSILE STRENGTH AS A FUNCTION OF EXPOSURE TIME
FOR MULTI-FILAMENT FABRICS OF POLYMIDE 6.6
(unprotected weathering)

Fig. 13



TENSILE STRENGTH AS A FUNCTION OF EXPOSURE TIME
FOR MULTI-FILAMENT FABRICS OF POLYMIDE 6.6
(protected against ultra-violet irradiation)

Fig. 14

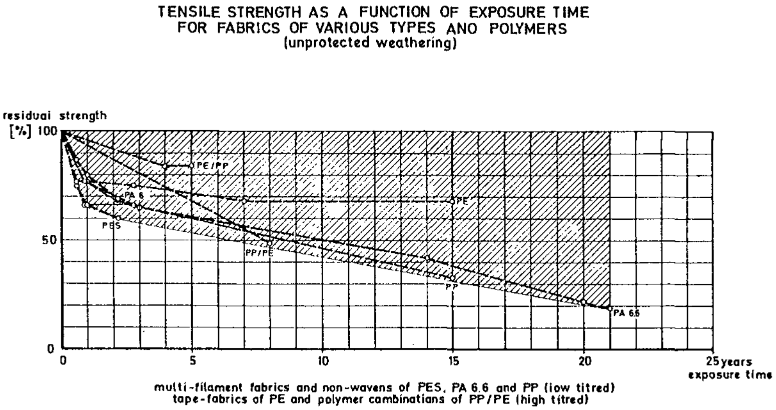

TENSILE STRENGTH AS A FUNCTION OF EXPOSURE TIME
FOR FABRICS OF VARIOUS TYPES ANO POLYMERS
(unprotected weathering)
residual strength
[%] 100
50
0
PE/PP
PE
PA 6
PES
PP/PE
PP
PA 6.6
0
5
10
15
20
25 years
exposure time
multi-filament fabrics and non-wavens of PES, PA 6.6 and PP (low titred)
tape-fabrics of PE and polymer cambinatians of PP/PE (high titred)

Fig. 15

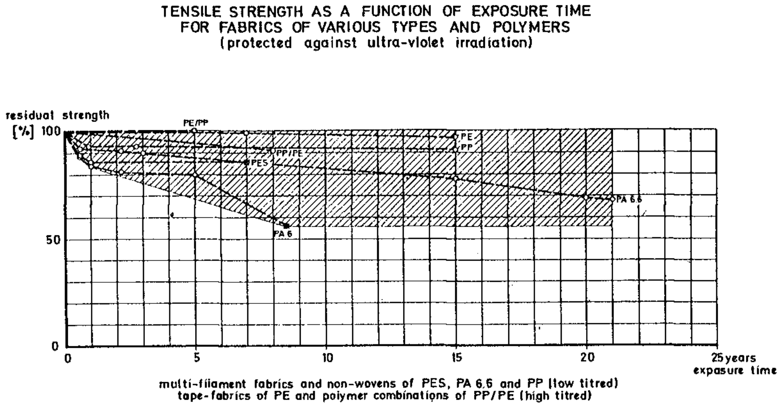

TENSILE STRENGTH AS A FUNCTION OF EXPOSURE TIME
FOR FABRICS OF VARIOUS TYPES AND POLYMERS
(protected against ultra-violet irradiation)
residual strength
[%] 100
50
0
PE/PP
PE
PP
PP/PE
PES
PA 6.6
PA 6
0
5
10
15
20
25 years
exposure time
multi-filament fabrics and non-wovens of PES, PA 6.6 and PP (low titred)
tape-fabrics of PE and polymer combinations of PP/PE (high titred)

Fig. 16

of tape-fabrics with polyethylene of polypropylene as base material is higher than the residual strength of multi-filament fabrics of polyester, polymide and polypropylene Comparable results are given by protection against ultra-violet irradiation (Fig. 16), but nevertheless in general the decrease in residual strength is lower as seen in Fig. 15.

By the interpretation of these results we have to consider that the fibre fineness is of great influence in long-term resistance of fabrics. Therefore the good results of the tape-fabrics, produced of relative thick tape threads, doesn't surprise. - The fibre fineness of the tape-threads is about some hundred dtex whereas the fibre fineness of filaments is only 5 to 10 dtex.

In addition we have to consider that the results determined at samples of the salt-water region could be influenced by a lot of parameters like suspended load of the seawater, duration of tidal overflow, covering of the fabrics by mud, seaweed, mikro-organism or rubble and their temporary variation. The damage of fabrics could also be caused by wave-action, drifting-wood, ice, shipping or tourists. Most of the parameters only influenced the sections with unprotected weathering like the upper sides of the sandfilled tubes. Synthetic filter fabrics in revetments protected by several cover-layers are less endangered but there is to pay attention that there is no damage of the fabrics during construction time.

Finally we can say that the most important parameters influencing the long-term resistance of fabrics in the salt-water region of the northsea coast are the ultra-violet irradiation and the raw material and fibre fineness of the fabric. Ageing by biological and chemical damages is of lower importance. Attention has to be payed that there is no damage of fabrics during construction time.

This results show fair agreement with results of investigations carried out on the woven synthetic filter fabric being a construction element of protection against scouring at the Eider stromsurge barrier. The protection against souring was damaged but the first supposition that the damage was caused by an insufficient long-term resistant of the woven fabric could not be confirmed.

In addition to the investigations on long-term resistance filtration rules have been development.

## FILTRATION RULES

A new dimensioning method to select a fabric allows, to fulfil and calculate the requirements of sand-tightness as well as the requirements of the hydraulic permeability of fabrics. Fig. 17 shows a flow diagram which explains the procedure to select a fabric according to the characteristics of the subsoil and the construction. In the first step we have to estimate the effective opening size $D_W$. $D_W$ is given by filtration rules as a function of the particle distribution curve of the soil and the load conditions.

In the second step the hydraulic conditions have to be controlled. To prevent over-pressures in a revetment-construction the permeability of the filter fabric has to be higher than the permeability of the subsoil. Special investigations were carried out to consider the decrease of the permeability of woven fabrics by blocking and non-woven fabrics by clogging. Now, as a result of the investigations, it is possible to estimate a permeability-reduction factor as a function of fabric data and soil characteristic. Only for non-woven fabrics, when the effective opening size is small in relation to the diameter of soil particles, an additional restriction is given by $D_W < 0.5 \cdot d_{10}$ leading to a $\eta_V$ value $\eta_V = 1.0$. The permeability of the fabric is sufficient when

$$\eta_{V/G} \cdot k_f \geq k.$$

The filtration rules to fulfil the sand-tightness are determined as follows:

| | |
|---|---|
| Static load conditions and $u \geq 5$ | $D_W < 10 \cdot d_{50}$ and $D_W \leq d_{90}$ |
| Static load conditions and $u < 5$ | $D < 2.5\ d_{50}$ and $D_W \leq d_{90}$ |
| Dynamic load conditions | $D_W < d_{50}$ |

Fig. 18 shows the diagram to estimate $\eta_G$. $\eta_G$ is given as a function of the standard test permeability coefficient $k_f$ and the soil parameter $d_{10}$.

$\eta_V$ is given as a function of the fabric parameters $k_f$ and P (Fig. 19). $k_f$ is the standard test permeability coefficient and P is named porosity of the fabric. P is defined as a product of the

voids ratio n
fabric thickness d under a load of 2 kN/m$^2$
and effective opening size $D_W$.

At times the application of this diagram is limited by the particle distribution of the investigated soils at the sampling locations. The range of the particle distribution curves are shown in Fig. 20.

Further investigations will be carried out to complete the diagram with $\eta_V$ as a function of the soil parameter $d_{10}$.

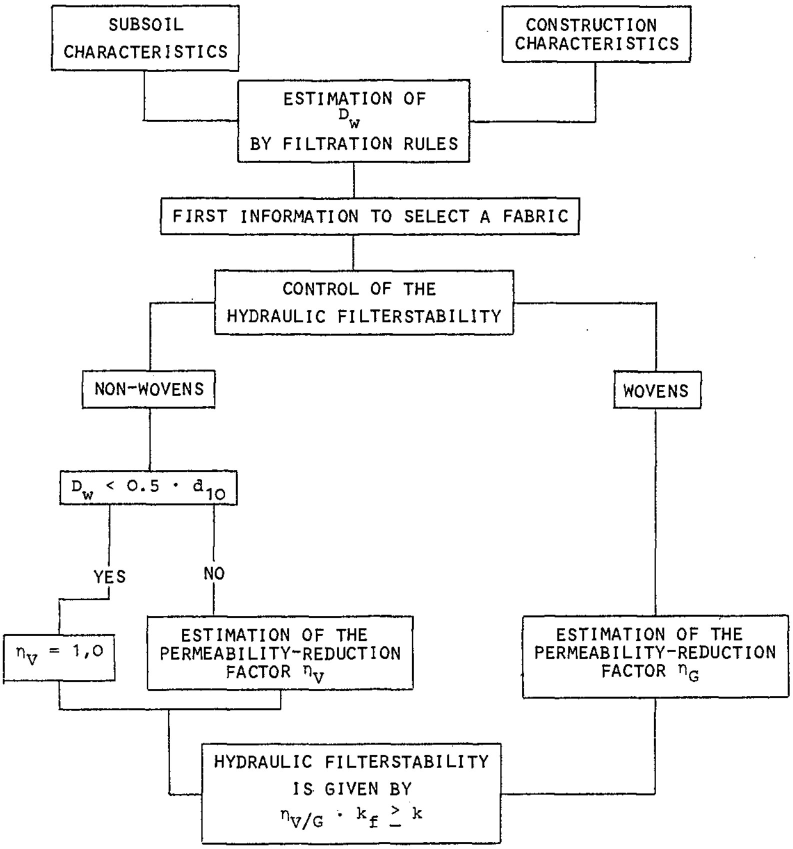


Fig. 17

Flow diagram to check the filtration properties of geotextiles

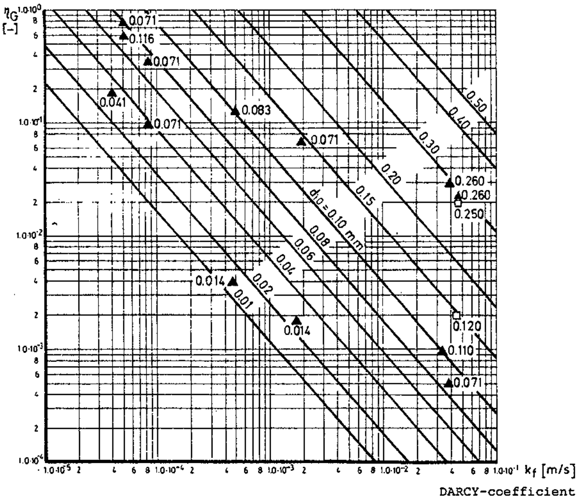


Fig. 18
Diagram to estimate the permeability-reduction factor $\eta_G$ for woven fabrics

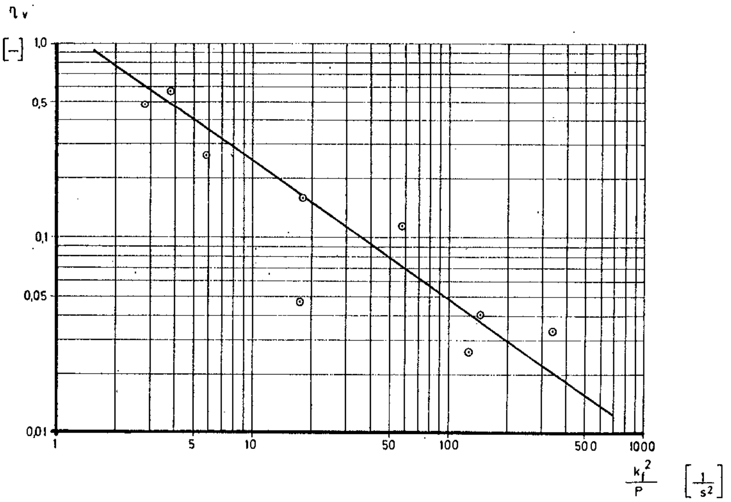


Fig. 19
Diagram to estimate the permeability-reduction factor $\eta_V$ for non-woven fabrics

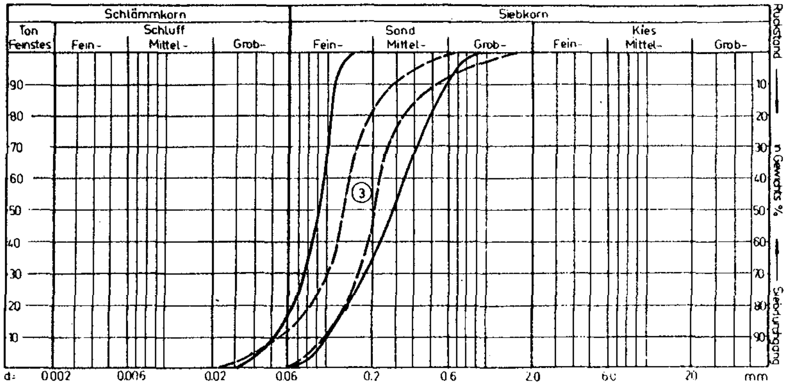


Fig. 20
Particle distribution curves at the sampling locations

## CONCLUSION

For applications in coastal engineering in the salt-water region of the Northsea coast the investigations on long-term resistance of fabrics lead to first satisfying results. The given filtration rules make it possible to select a geotextile according to the special requirements of the application given by the particle distribution curve and the DARCY-coefficient of the soil. Some additional investigations will be carried out at the FRANZIUS-INSTITUT in the near future.

## REFERENCES

1. BOURDILLON, M.: Utilisation des textiles non-tissés pour le drainage. Laboratoire central des Ponts et Chaussées, Lyon, 1976

2. ERCHINGER, H.F. u. SNUIS, G.: Kunststoffgewebeschläuche im Küstenwasserbau. Wasser und Boden, 24. Jahrg. (1972), Heft 1

3. GIROUD, J.-P. u. PERFETTI, J.: Classification des textiles et mesure de leurs propriétés en vue de leur utilisation en géotechnique. International Confernece on the Use of Fabrics in Geotechnics, Paris, 1977, Vol. II

4. HEERTEN, G.: Geotextilien im Wasserbau - Prüfung, Anwendung, Bewährung. Mitteilungen des FRANZIUS-INSTITUTS für Wasserbau und Küsteningenieurwesen der Universität Hannover, Heft 51, 1980

5. ZITSCHER, F.F.: Kunststoffe für den Wasserbau. Bauingenieur-Praxis, Heft 125, Verlag W. Ernst & Sohn, Berlin 1971