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SELECTION OF GEOTEXTILES FOR DRAINING SEDIMENTS IN INDUSTRIAL DECANTERS

SELECTION DE GEOTEXTILES POUR DRAINER LES SEDIMENTS DANS DES BASSINS INDUSTRIELS DE DECANTATION

AUSWAHL ENTSPRECHENDER GEOTEXTILIEN FÜR DIE DRAINAGE VON SEDIMENTEN IN INDUSTRIEABSETZBECKEN

The article discuss laboratory tests on the selection of most appropriate geotextile fabrics used as pipe cladding for the drainage of strongly alkaline industrial waste stored in sediment tanks, and reports on model test findings concerning various types of screens to speed up settling of sediments.

Im Artikel werden Laboruntersuchungen besprochen, die geführt worden sind zur Auswahl entsprechender Geotextilien für die Entwässerung stark alkalischer Industriebecken. Darüber hinaus sind Modelluntersuchungen an Entwässerungsschirmen, in deren Ergebnis es zur Absetzung von Sedimenten kommt, dargestellt.

INTRODUCTION

Flexible PVC drain pipes clad with geotextile fabric and provided with flow screens were applied for the drainage of sediments collected in industrial tanks containing soda waste deposits, in lieu of the conventional ceramic or stone drainage systems.

Altogether five types of geotextiles were subjected to laboratory testing to find the most suitable material for the purpose. Then a programme and project was prepared for site investigations in the actual tanks.

Geotextile fabrics were tested in order to determine their tensile strength, across and lengthwise, on a piece of fabric; also to test the behaviour of geotextiles while staying in the sediment, aided by hydraulic testing in a filtration column to assess the coefficient of permeability plus model tests to evaluate the sediment - geotextile material interactions when using different types of screens.

Tensile strength is not among the most stringent requirements for geotextiles used in drainage. On the other hand, its changes in the course of stay in the sedimental environment are an essential factor indicating the progress of degradation.

The geotextiles subjected to testing, arbitrarily termed as types A,B,C,D and E, were made of various waste raw materials; thus: geotextile A - of polyester; geotextile B - of polyester - natural fibre waste blend; geotectile C - of polypropylene and polyamide filament as weft on jute or linen warp; geotextile D - of polypropylene and polyamide blend; geotextile E - made of fibre glass.

The geotextiles were immersed in sediment and sampled for tensile strength testing for several times after their successive period of stay in this medium. The obtained results are presented in Fig. 1. Until recently, our investigations cover tensile strength and elongation tests on samples of the above mentioned fabrics throughout an 18 months' period of immersion in sediment.

1. Analysis of tensile strength test findings

Geotextile A, polyester-made, features the highest intensity of the degradation process during the initial months of staying in the sediment when the fabric loses as much as 74% of its original strength when tensioned longitudinally and 84% with transverse tensioning of the fabric. In the subsequent months of immersion in the sediment, however, tensile strength of geotextile A tends to stabilize and its pronounced degradation process is hampered. Thus after 18 months' exposure to sediment influences the tensile strength of test specimens practically was found unaltered versus the strength action, the strength level fluctuations are well within the measurement error.

On geotextile B made of polyester blended with natural waste fibres the intensity of the degradation process due to the sediment medium takes a similar course as for geotextile A. Still, the decrease in tensile strength after the four initial months of stay in the sediment is less and it averages 23.5% when tensioning in both directions. Admittedly, there is a certain minor strength decrease during the following months. Only after 18 months of testing a very substantial loss of 75% strength was disclosed in the transverse direction of tear of the test piece. It is rather difficult to explain the reasons for the finding as it is obviously needs retesting to be done in a full measurement run to confirm or refute this result.

The degradation process of geotextile C made of polypropylene and polyamide filament yarn on jute and linen warp is basically different from that of geotextiles A and B. The strength increment obtained during the few first months of the fabric staying in the sediment, of a 2% through 25% order, is gradually stopped and after 18 months there is a slight 4 or 5% decrease versus the initial strength value.

There is a still different pattern of the degradation process with geotextile D, made up of polypropylene and polyamide blend exclusively. Its strength after 18 months' immersion time was found to be persistently higher by 5% longitudinally and by 7% less when tensioned in contrast to the original strength values.

Now geotextile E, made of fibre glass appears to have lost nothing of its original characteristics after those 18 months of testing in sediment. Still, as the recorded changes do not exceed the possible measurement error which tends to be rather high with low load values /the breaking machine is coupled to tensometers across a Hottinger bridge, from which readings of breaking load values are taken/, our final evaluation of the degradation process with the fibre glass geotextile must be postponed until the moment when the effect would become apparent to visual appraisal.

All the geotextiles subjected to tensile strength test after the successive immersion periods had their elongation values less than original.

When analysing the progressing degradation of geotextile fabrics in the strongly alkaline environment of soda industry waste, where pH number is equal, or higher than 10, with high calcareous content present, we can say that polyester-made fabrics are more liable to polymer degradation than those of polypropylene, polyamide and fibre glass.

2. Permeability of geotextiles

Hydraulic tests were carried through in a filtration column /Fig. 2/ with variable directions of water flow to each sample of the tested fabric. Water was fed to the column by gravity from above and then from below, enabling to check the measurements for correctness, and also to find the optimum manner of wrapping the geotextile around the drain: with its bulky or smooth side, and ribbed or smooth side in the direction of water flow entering the system.

To estimate the coefficient of permeability k, laminar water flow was assumed to take place in the geotextile, involving the validity of Darcy's law:

$$v = k \ i \ ; \ k = \frac{v}{i} = \frac{Q \times \delta}{A \times \Delta H \times t}$$

where:

v - seepage velocity through the geotextile, m/s; k - coefficient of permeability; i - hydraulic gradient; Q - total flow volume; δ - thickness of geotextile fabric; A - area of flow; ΔH - decrease in hydraulic head; t - time of flow.

Owing to the fact that the tested fabrics are different in their structure, rather high differences were obtained for the coefficients of permeability on various samples made of identical raw material. The most disadvantageous value obtained was selected as basis to compare the viability of any of the tested fabrics to co-operate with the actual sediment in soda industry waste tanks.

The inequality that must be fulfilled to retain the criterion of permeability is

$$k_g > 20\ k_s$$

where:

k_g - coefficient of permeability for the geotextile; k_s - coefficient of permeability for the sediment.

The latter, as found in the sediment tank, oscillated between 5×10^{-6} and 5×10^{-8} m/s.

The values of the coefficient of filtration for the particular geotextiles and for a flow vertical to the piece of fabric are as follows: geotextile A - $1.02-2.50\times10^{-2}$; geotextiles B - $0.80-1.50\times10^{-2}$; geotextile C - $0.70-1.20\times10^{-2}$; geotextiles D - $0.40-1.50\times10^{-2}$; geotextiles E - $0.40-1.50\times10^{-2}$ m/s.

As all the coefficients of permeability obtained by us with any of the tested geotextiles satisfied the inequality, the seepage criterion was retained and the geotextiles found suitable to be installed in the sediment tank.

The geotextile type chosen to be used in conjunction with the sediment of soda waste was the one displying least degradation degree in this environment, in the function of time.

Hence geotextiles C and D were recognized as more suitable, considering their least degradation degree in the operating conditions.

3. Model tests

Model tests of drainage systems, incorporating flow screens and unscreened respectively, were run in parallel with the remaining test types, to evaluate their efficiency. Model tests were carried through in five glass cylinders with orifices drilled in their bottom part for the entering of drains from below. The drains were clad with geotextiles and flow screens of various types could be arranged on them. The test stands thus prepared were poured over with sludge sampled from the sediment tanks on site. Water discharging from the drains was collected into measurement flasks, with its volume thoroughly checked during the whole measurement period. Thereupon, after complete seepage, it was poured back again into the respective test tanks. The change, if any, in seepage velocity permitted to assess the period of changes taking place in the sediment participating in the drainage together with the geotextile; and also evaluate the efficiency of the applied flow screens.

Three types of flow screens operating in conjunction with the drains were tested; these are

- Drain I - with a single screen
- Drain II - with a double screen arrangement
- Drain III - with a flat screen;

as well as drains with two types of cladding, made of geotextile A and B respectively. The time of liquid seepage from the drain in geotextile cladding was fairly constant, and hence it was used as reference to compare the efficiency of the screens provided on drain pipes /Fig. 3/ . It can be inferred from the shape of the waveforms illustrating the sums of liquid discharge from the drains that during the two first fillings of liquid minute sediment particles are displaced to form something like a lining around the drain which gradually reduced the increments of the discharge volume. At the time of liquid seepage during these three initial cylinder fillings the phenomenon gradually tend to stabilize until a complete equilibrium was reached during further refilling, when no fluctuations in the discharge volume were observed till the attainment of 90% of the total discharge volume.

Our findings concerning the various flow screens arranged on drainage pipes to be used in a soda waste sediment medium indicate the efficiency of those screens in laboratory conditions, when referred to geotextile-clad drainage pipes to be

- Drain I , with a single screen - 166 to 440% efficiency
- Drain II , with a double screen - 195 to 463% efficiency
- Drain III , with a flat screen - 83% efficiency.

The above values describe the effect of screens when operating in conjunction with drainage pipes, considerably accelerating or delaying the time involved in water seepage from the sediment, depending on the type of screen applied.

The findings from our model tests on the efficiency of the particular screen types may not be interpreted in terms of quantity, even though a qualitative evaluation demonstrates quite essential differences in the time needed for the drainage of water from the sediment. Hence it appears viable to carry out full-scale field investigations on the existing industrial waste tanks, especially as different sedimentation rates were assessed with sludge during the model tests while draining the particular test cylinders.

At the second stage of model tests under continuous flow conditions and with liquid level kept constant in the test cylinders with a double and a single vertical screen, the sedimentation rate was found to be the highest and most rapid, to the effect that sediment /waste sludge/ had to be replenished. Otherwise the screens would soon emerge from the sediment, rendering any further testing impracticable.

4. Site investigations

The purpose to carry out field investigations of pipe drain installations with the use of seepage screens was to check the efficiency of such seepage screens in respect of

- their screening ability when installed in soda waste tanks,
- volume and discharge rate of waste water,depending on the design solutions applied,
- changes that take place in the drains and screens during their operating in waste sediment tanks, gradually as sediment layers increase in thickness during the successive tank fillings,
- changes in the deposition of sediments in way of the designed screens and drainage systems versus their sedimentation rate in tanks having no drainage.

Drainage systems are installed in industrial waste sedimentation tanks in order to stop water seepage as far as possible and prevent its penetrating from the sediment to the chieve good compaction of waste by quick drainage and reduce pressure in the proximity of tank walls.

Flow screens applied in drainage systems considerably add to the area of water reaching the drain pipes and because permeability of the geotextiles is substantially better than that of the sediment, a quick and efficient filtration path of water filling the drain is formed, thence to pass to a drainage ditch, reducing the amount of salt-containing water seepage into the soil.

The consolidation of sediments by quick drainage of waste water will lessen the sediment volume and add to the tank storage capacity in the existing waste tanks in use.
Water drainage from the areas in next proximity to the tank walls will improve the stability and safety of those structures. There is a drainage system test project providing for four types of flow screens to be installed along two sediment tank walls. Further two drainage paths, made of flexible PVC piping clad with geotextiles are to be laid between those screened drainage paths to check their screening effect.

The test installation project makes provision for

1. flat screens to be placed above a drainage path; the arms of those screens are to be arranged with some obtusion;
2. single vertical screens to protrude above the hight of a laid drain pipe, extending through the whole length of its geotextile cladding;
3. double screens, having their arms inclined at an angle of 45° to the horizontal and supported in trestles;
4. discontinuous screens, with their arms protruding in segments above the drain hight;
5. PVC drains clad in geotextile fabric, to constitute a reference component for the drainage system investigated.

After the drainage system will have been installed in a sediment tank it is anticipated to provide for continuous measurements of the volume of water discharged from the drains, the variations in water level in piezometric pipes placed in way of the drain pipes and behind them, and also to measure the thickness of the sediment layer building up during the successive tank fillings. Further, the tank walls are to be raised up to the project ordinate, established at an about +15 m hight above the tank bottom level.

CONCLUSIONS

1. All the tested geotextiles meet the criterion of filtration and there is no objection against use for the drainage of water from soda industry waste sediment tanks.
2. Polypropylene/polyamide-made geotextiles are comparatively better suited for the purpose, as their degradation in salt-containing calcareous and strongly alkaline waste water is found to be considerably less than that of polyester fabrics. Consequently higher viability of geotextiles C and D has been confirmed by us.
3. The issues of model tests with flow screens applied do not go beyond qualitative assessment. Any quantitative determination would require site investigations to ba carried through, to check the efficiency of the proposed solutions.
4. Similarly our findings on time-dependent settling of the sediment during drainage with the use of screens in laboratory test conditions are also qualitative only. It will be necessary to run additional site investigations to evaluate them in terms of quantity.
5. Site investigations on the industrial waste drainage problems ar worth while and well motivated.

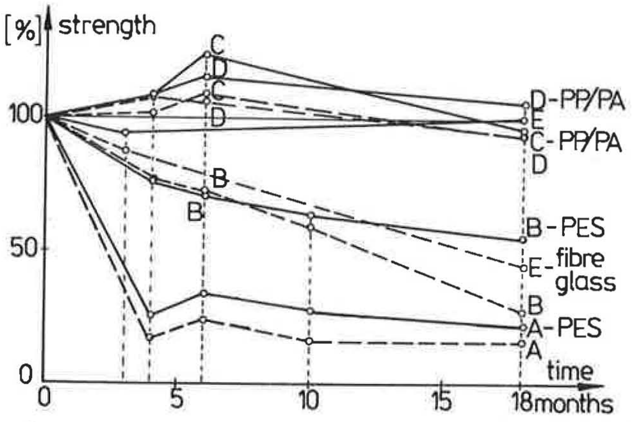

Fig. 1. Tensile strength as function of geotextile degradation in sediment
when extended longitudinally
for transverse tensioning

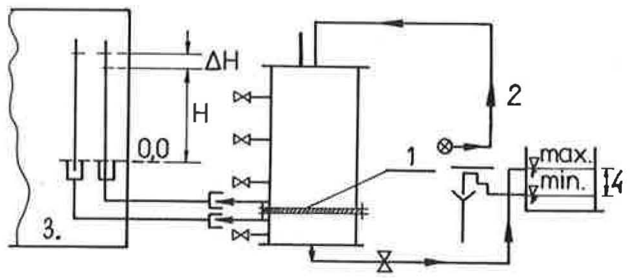

Fig. 2. Flow diagram of test stand to check water permeability of the geotextile with vertically directed flow.
1. geotextile
2. water flow direction
3. piezometer board
4. water level max. and min.

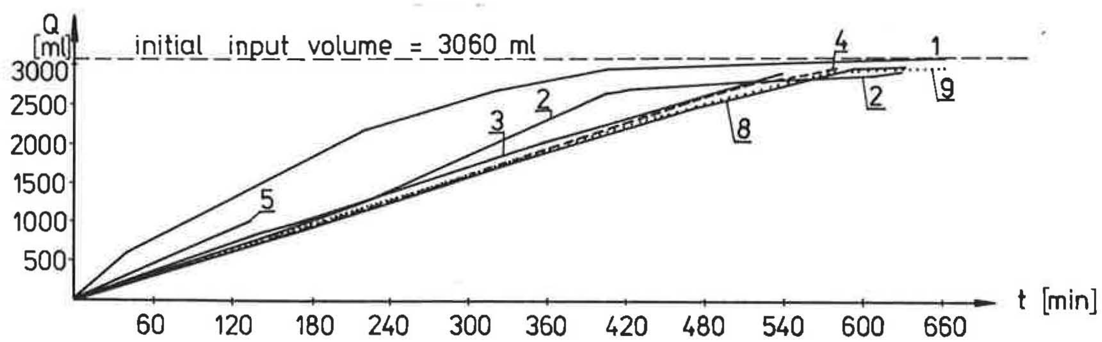

Fig. 3. Discharge volume of a geotextile clad drain pipe. Liquid fillings 1 to 9.

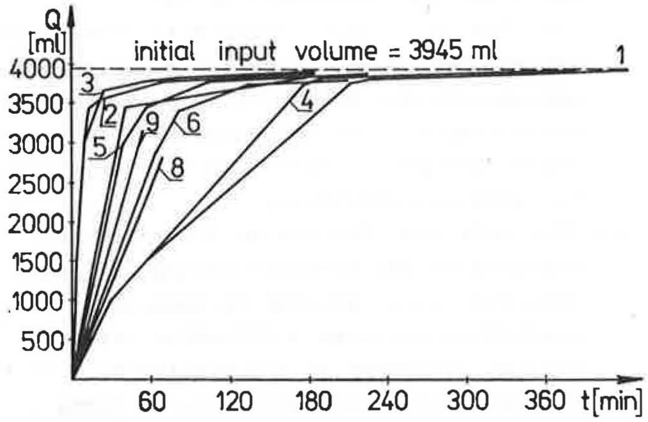

Fig. 4. Discharge volume of a drain pipe with single-screen geotextile cladding. Liquid fillings 1 to 9.

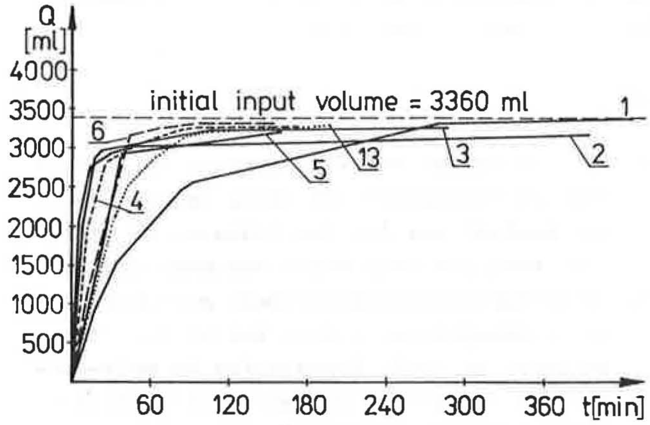

Fig. 5. Discharge volume of a drain pipe with double-screen geotextile cladding. Liquid fillings 1 to 13.