INCREASING THE SAFETY OF TAILING DAMS USING GEOTEXTILES AND GEOGRIDS

Franz List

Pfeuferstrasse, 4
81373 München, Germany
Phone: + 49 89 7253133, Fax: + 49 89 7469067

INTRODUCTION

In the course of the IMWA'99 Congress there will be reported on the latest knowledge and development as well as the standard of technique of tailing dams. In mining companies these buildings are necessary for operation. These embankment dams and buildings often have immense volumes and reach highnesses of water which correspond to those of real barrages as they are built for the power plants, drinking water reservoirs or other different purposes. National as well as international these buildings have an exceptional position though. As far as I know the building and the security requirements of these plants –which are mainly set up on the company area of the operator and are therefore often not accessible- are legally not bound to the valid rules and instructions of DIN or other institutions as usual in the normal building of embankment dams. In Germany it is planned to comment on the tailing dams in an addition to the valid DIN 19700 in leaf 15. In the course of the ICOLD-meetings proposals concerning the building and running of tailing dams have been made as well, as for example in the Bulletin 106 (ICOLD, 1996). The authorities lack the performing guidelines though, above all the official introduction with instructions for plans and calculations for the project and the consequent application is not laid down obligatorily.

SAFETY OF EMBANKMENT DAMS

We all know that there cannot be any absolute security but the risk of a dam failure should be kept as small as possible. By detailed rules and notes to the necessary inspections as well as measuring- and control-installations online we can fulfil these requirements. "Safety first"! should be our top motive. In spite of the knowledge from science and research and the great possibilities for testing the subsoil and the different embankment material especially with tailing dams there seems to be a greater risk. In the past year there were again immense damages and even catastrophes have happened to nature by failures of tailing dams. The catastrophe of Stava is still an awful memory for all of us (Brauns, 1992).

Therefore we should seriously ask whether this is only due to the execution in building or if these consequences have been caused by understating the known basic rules. Even a tailing dam of only 5 m height has to be planned, build and inspected very carefully. The problems are often due to the requirements in these buildings. Especially tailing dams are meant to be built as cheap as possible and often the embankment dams are even set up with problematical dam material. In this report it is not referred to the preliminary examinations and the plants though, this should surely be demanded in detailed procedures and stated separately. World-wide hundreds of tailing dams are running, surely there are also a lot which are out of order where you should question the safety standard. Being a civil engineer who has handled questions of security in hydraulic engineering and the building of embankment dams for decades and still in this business I would like to report on the experience we made with the use of geomembranes and geogrids in geotechnique to give my share in the rising of the safety for existing as well as planned plants. Beside the basic functions of separating, straining, filtration and sealing in the building of tailing dams geotextiles, geogrids and other geosynthetics can also improve the safety against dangers of suffusion and erosion. In our technical tasks geogrids and geotextiles have proved excellently.

CAUSES FOR DAM FAILURES

First of all the knowledge of the reasons which lead to a failure or the breaking of a dam has to be made clear. Here you can proceed from 2 basic causes:

- a static reason for the failure;
- a hydraulic reason for the failure.

Sowers (1972) has shown these reasons for the failure in detail.

With a building as complex as an earth-fill-dam there is mostly more than one reason which leads to the failure (Figure 1). The reasons of dangers we have in embankment dams are therefore largely known. By according carefulness in the planning of the construction, the building, the starting storage

and last but not least a good control-system during operation and the behaviour we can contribute a big deal to the safety of tailing installations. Above all the safety against erosion, suffusion and arching as well as piping should always be mentioned. Too high loads on the subsoil and building material which leads to high pore-water pressure can also cause dangers. In embankment dams of tailing dams the stability of the dams and the usability of the sealing systems also have to be proved by engineering conceptions and calculations. For tailing dams which use very different dam building materials, above all the method of construction for the hydraulic fill dam is hard to control and therefore has to be controlled in a special monitoring system. By using geotextiles these insecurities can be avoided (Giroud, 1992).

SYNTHETICS IN GEOTECHNIQUES

Fleeces and factory-made geomembranes have been offered and used in hydraulic engineering and the building of barrages for over 30 years now. 1977 the first congress for the application of geotextiles in the building of earth- and rock-fill dams as well as in hydraulic engineering took place in Paris. At that time Prof. Dr. Giraud spoke about the variety of application possibilities and advantages of geotextiles in a splendid speech. This speech showed a vision. Today after more than 20 years this vision has become true. Millions of square meters of geotextiles are installed world-wide each year. There is nearly no greater site where geotextiles are not applied. The triumphal procession of geosynthetics even goes on though. The engineering companies in all countries have attended to the examination of this building adjuvant. In Germany an own special section "Geotechniques" has also been founded in the course of the "Deutsche Gesellschaft für Erd- und Grundbau (German Association for Earth and Foundation Engineering)". By new calculating methods the prove for the efficiency of geotextiles and geogrids is exactly determined. There are 1- to 3-layered non-wovens, different compositions of non-wovens and a whole range of combinations with grids. World-wide aimed applications and calculating methods for geomembranes are worked out in research and congresses. Due to this geosynthetics and geogrids can increase the safety of our earth constructions.

The reasons for the use of geosynthetics are:

- reduction of material,
- shortening of the working hours,
- less abrasion of the equipment,
- better control-possibilities,
- higher requirements to the building,
- lower costs.

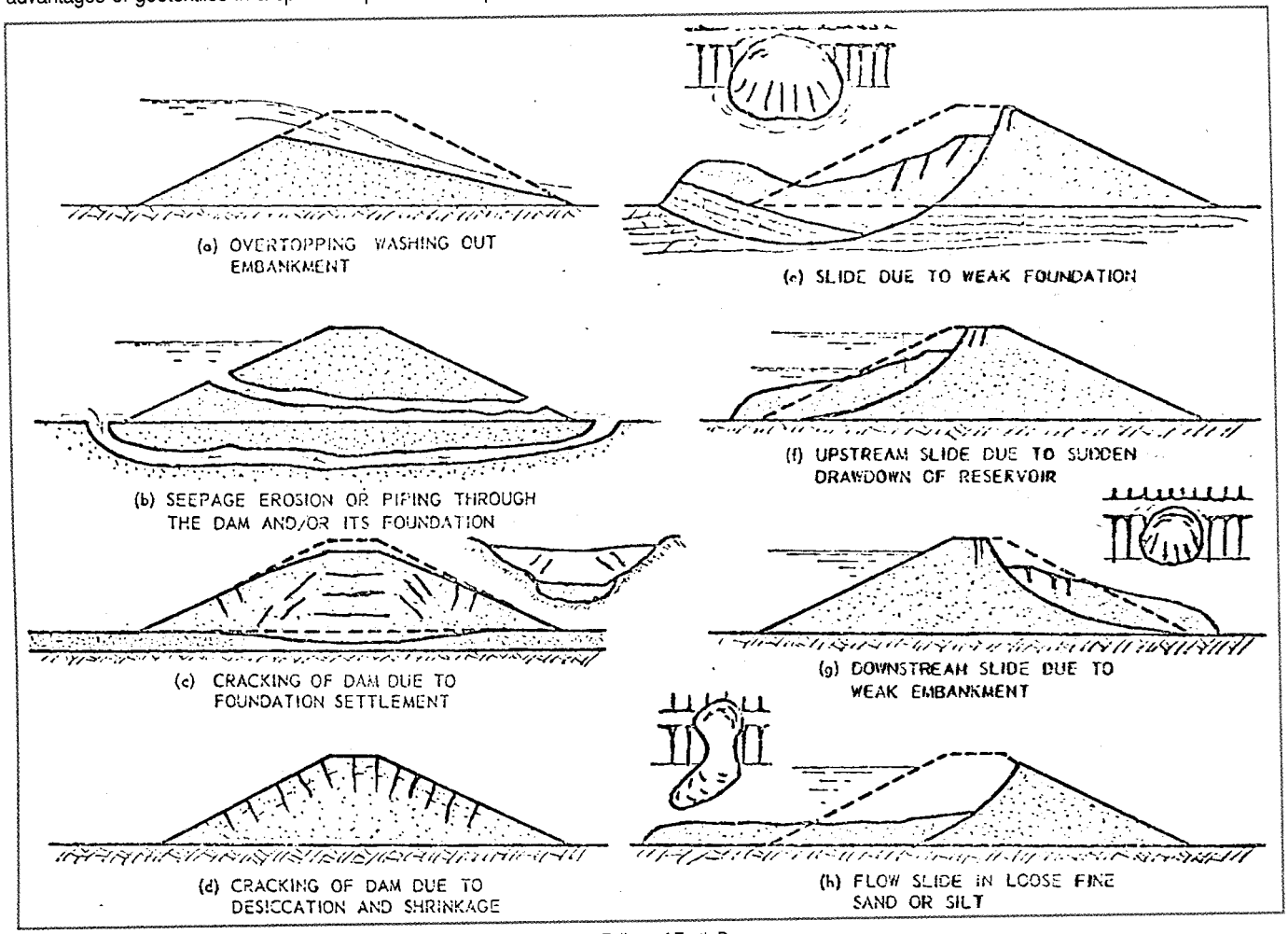

Figure 1. Failure of Earth Dams.

Further great advantages of geosynthetics can be mentioned:

- geosynthetics can exactly be adapted to the function they are to fulfil,
- geosynthetics can easier be dimensioned because they are manufactured industrially and therefore have a steady quality,
- geotextiles need a small transport capacity,
- geotextiles are quite easy to install,
- geotextiles are not dependent on the weather when they are installed and,
- geotextiles have a long term durability.

Nowadays geotextiles are offered by a lot of companies. They are manufactured in different production processes. Therefore the choice can be made according to the requirement of the application. In detail normally the following kind of geotextiles are on the market:

- needle punched geotextiles (smooth and extensible),
- thermal strengthened geotextiles (stiff and thin),
- chemically bound geotextiles (stiff),
- woven geotextiles (with high strength fibres),
- compacted materials with all kinds of geotextiles.

Geotextiles are also used to solve special problems:

- sand trap mats with claw layers on thermal strength or needle punched geotextiles.
- draining mats (with open holes in the middle part).
- sealing mats with Bentonite between 2 needle punched geotextile mats.
- sand mats (heavy for filter and separation use under water).

They all serve as filtration- or separation-layers and thus avoid erosion and suffusion. Drainage mats can be used to drain off of seepage water. Besides there are geomembranes with grid-structures, so called geogrids which have a very high tensile strength. They can be used as reinforcements in landfill applications (geogrid and aramid). Hereby the subsoil conditions can be improved. The use of geotextiles is nearly unlimited. The Bentofix-mat can be used as an impervious blanket. The permeability is K 10^{-8} to 10^{-11} m/s. There is a very special geotextile for each application. With the right choice and dimensioning the stability of the dams can be increased. Due to the large number of products and the required functions the success of the application is depending on expert dimensioning. Only companies which can prove to have worked on such projects before should have the care of the according planning, deliveries, installing and the quality control. A certification according to DIN ISO 9000 should be proved.

POSSIBLE STEPS FOR INCREASING THE SAFETY

By using geotextiles in embankment dams and dikes the stability can be improved immensely with simple means. In Figure 2 probable applications of geotextiles in the embankment dams and in dam construction are shown basically.

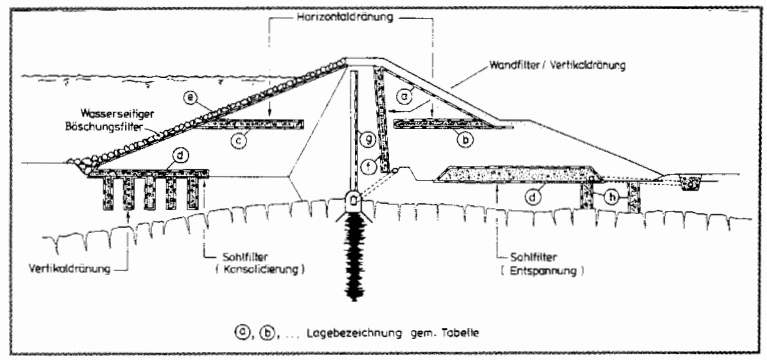

Figure 2. Possible applications of geotextiles in retaining dam construction (DVWK, 1989).

For steep slopes the construction of a surface infiltration by the means of geotextiles can effect an increase of the stability of the slope even with heavy rain.

The installation of geotextiles on the dam crest (Figure 3) is a successful and an established applicability in case of unforeseen insignificant overflow of the crest.

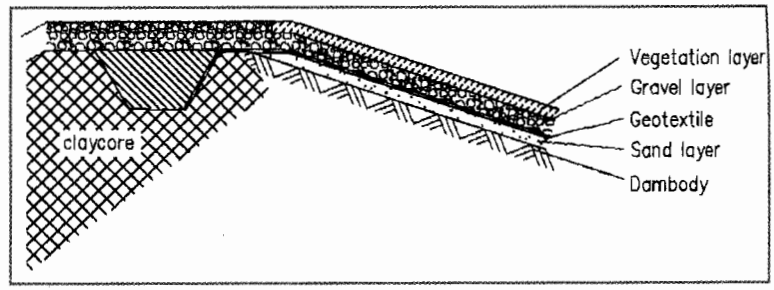

Figure 3. Geotextile on the downstream face of a slope as surface protection and protection of the top in case of an overflow.

For the protection of the upstream face of dams filter mats with different functions are chosen (Figure 4). They serve as separation-layer and filter.

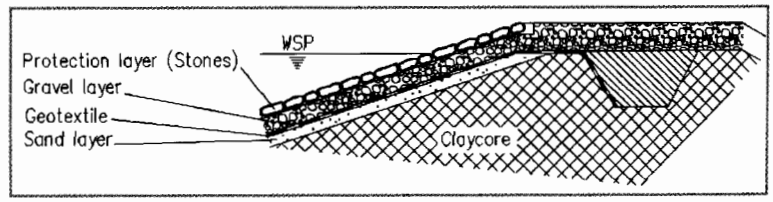

Figure 4. Geotextile on the upstream face as separation layer and filter.

A further application which is often necessary for increasing the stability of the upstream faced slopes is the installation of horizontal filter on the upstream face of the dam (Figure 5). For the stabilisation and for drawing down of the pore-water over pressure on the upstream face of the dams filters with a geotextile sheathing can bring a noticeable increase of the stability of the slopes. By a fast sliding of the upstream faced slope it avoids a sliding of the upstream faced slope by a fast draw down. In picture 5 this possibility is shown in detail.

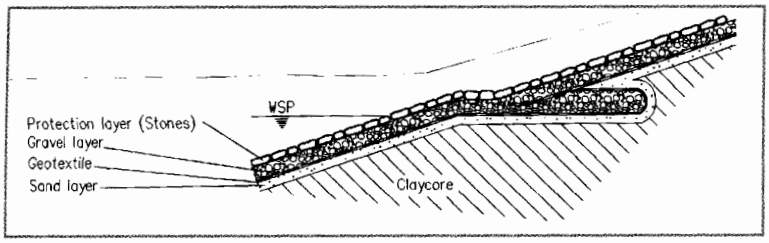

Figure 5. Surface filter with geotextile sheathing for increasing the safety of the slope in case of fast draw down or unsuitable dam material without sliding resistance.

In Figure 6 geotextiles are used for elongation by an impervious blanket and protection against flow under the dam as well as avoiding of piping is shown. The execution can be effected with a geotextile sealing mat (e.g. Bentofix). The elongation of the seepage way brings a clear increase of the safety.

The picture shows an elongation of the seepage way at the same time in connection with a geogrid for increasing the solidity of the subsoil respectively for the equal distribution of loads.

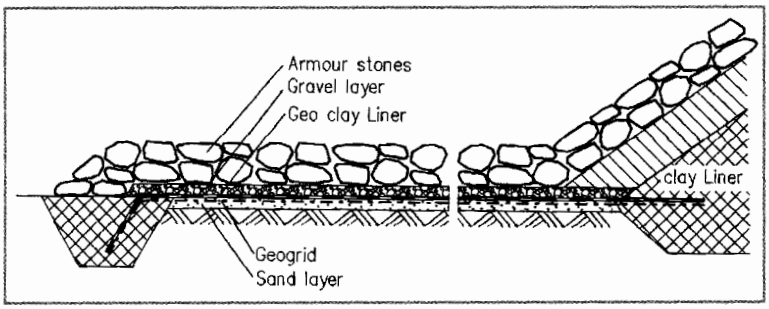

Figure 6. Elongation of the seepage way with geosynthetic liners for avoiding of piping.

For the increasing of the stability of the upstream faced slope on sensitive subsoil against settlements the construction of a geotextile filter with drilled gravel pillars covered with geotextiles is necessary.

The picture shows the possibility of applying the geotextiles with gravel pillars (Soft-Soil-Piles, SSP). For increasing the safety on subsoil sensitive against settlements gravel pillars with filter-stable geotextile sheathing and geogrid can be chosen. Hereby not only a reduction of the pore-water over-pressure in the subsoil is achieved but also a settlement which brings a stabilisation of the subsoil. The gravel filling allows a fast draining off of the infiltrating water. In connection with a surface filter built on top this part of water can be drained off then.

In addition an increase of the safety against foundation failure respectively gliding of the toe of the dam can be achieved in connection with a geogrid as reinforcement. The special construction of the ICR-grid of a geogrid with applied needle-punched non-woven grants that no mixture of materials takes place under hydraulic strain and that the tension can even be taken up on a long term without considerable losses in the solidity. The reinforcing effect has already been proved in a load bearing test, depending on the material used for the carrier layer and the thickness of the construction, load bearing reinforcements of up to 80 % in comparison to the use without geomembranes have been noted (Floss, 1999). The installation is especially suitable on the upstream face under the dam ground. It can also be used on the downstream face under the dam for expansion (Figure 7).

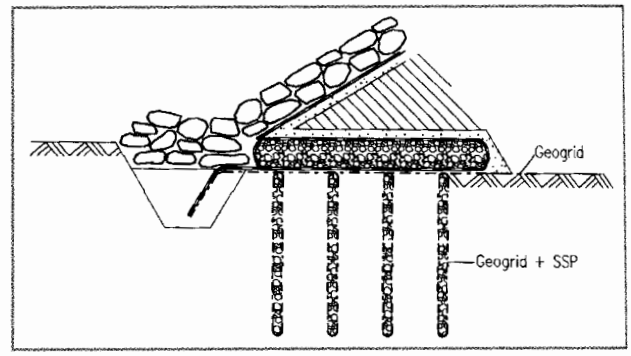

Figure 7. Shows the installation of a horizontal filter with vertical drainage and a geogrid with high tensile strength.

In the inside of the dam geotextiles can also help to increase the safety. The Figure 8 and 9 show possible applications for the installation of geotextiles as filter for protecting the core and also for securing the rock-fills in hydraulic fill dams.

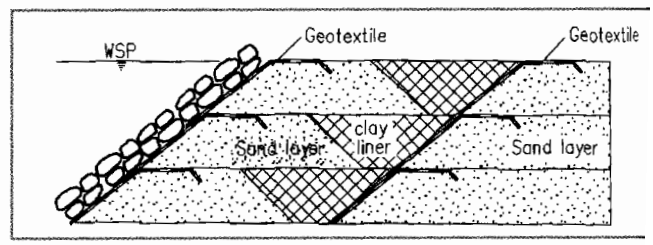

Figure 8. Installation of geotextiles as filter in the dam (hydraulic fill dams).

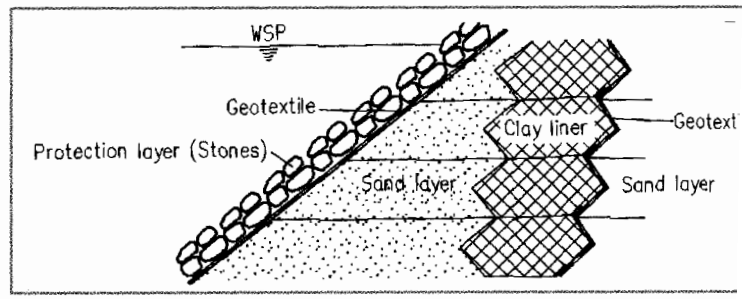

Figure 9. Installation of filtermats behind the core (hydraulic fill dam).

In the inside of embankment dams leakage water through the core has to be drawn down as fast and effective as possible. This can be done with geotextiles (drainage mats). An additional installation of an expansion pillar filled with gravel and geotextile sheathed can help to draw down the water (Figure 10). The connection to the toe drain is necessary.

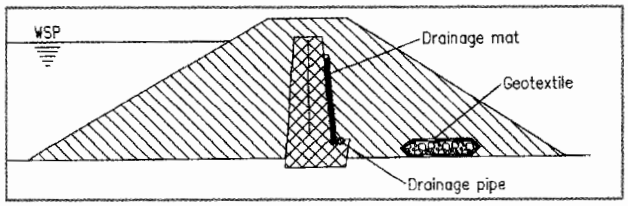

Figure 10. Expansion drain on the downstream face of the core.

Geotextile sealing mats (Bentofix-mats) can also be installed on the upstream face in order to improve the sealing effect of the core (Figure 11).

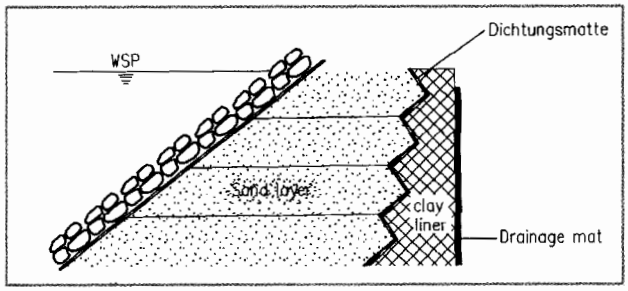

Figure 11. Installation of sealing mats.

In Germany there are great experiences and even instructions with all necessary requirements for the execution in the field of building and protection of waste landfills. Hereby basis sealings are demanded very often. Even the capping of such landfills is usually done with geotextiles nowadays. Sometimes tailing dams from mines which are out of order are now used as waste landfills. In this case (like e.g. in the waste landfill Hausham, Bavaria) extensive stabilisation works in the subsoil and basic sealings are necessary. In Hausham this problem was solved with geotextiles and geogrids. In river engineering geotextile big-bags have proved well for the manufacturing of a base sill and a training dike lying under water.

EXAMPLE

In one example I would like to refer to our experiences with the application of geotextiles in Bavaria.

Drinking water reservoir Frauenau

In the approximately 84 m high dam geotextiles were installed for 3 different functions (Figure 12):

- geotextile in the core for protection against erosion in case of cracking
- geotextiles as filter and passage between decomposing material and rock-fill.
- geotextiles for protecting the core trench and as filter.

The geotextile (3) is divided in 9 parts by vertical partition between the sealing wall and the downstream faced part of the core. At the lower edge of the geotextile which is bound into the control passage with a special arrangement and filter stones, the water pressure is measured in 32 parts of the geotextile with pressure gauges. Hereby they provide a comparative value of the pressure conditions in the geotextile and its surrounding.

The drinking water reservoir is in operation since 1980. The seepage water has not changed since the first impoundment. The installation of geotextiles has therefore proved fully well (Seethaler, 1985).

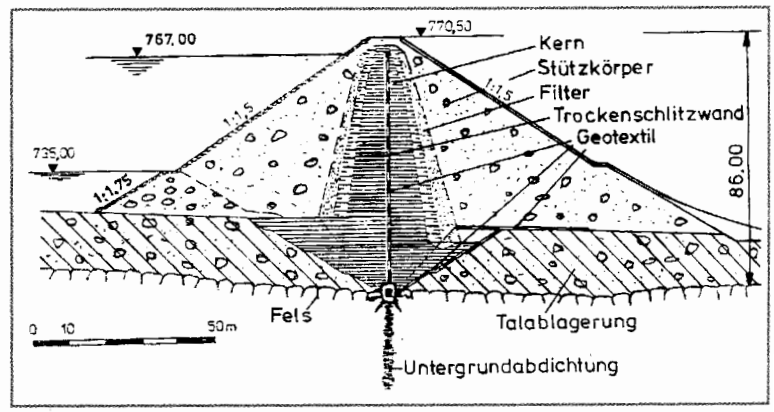

Figure 12. Frauenau-dam, cross section of the dam and details of the control passage.

SUMMARY

In the past 25 years in Bavaria the use of geosynthetics in hydraulic engineering and embankment dams has proved to be very good. It is a valuable share to the increase of the safety of our buildings. In our work Terrafix non-wovens with a thickness of > 4,5 mm and a weight of > 600 g/m^2 have proved to be best. Furthermore we made positive experiences with uniaxial pre-stretched Tensar geogrids. Due to the various properties of geotextiles they can help immensely to reduce the dangers our earth- and hydraulic buildings are exposed to. Geotextiles can not only grant the stability of the filters and reduce the erosion but by the combination of geotextiles with high strengthened geogrids static strains can be taken over as well. Geoclayliners and PEHD-Membranes can replace thick clay layers as sealings (List, 1989; Dressler, 1994; Rau and Dressler, 1994; Floss, 1999; Heerten, 1999).

A safe dimensioning, a perfect construction and a careful installation help to reduce the dangers. The installation of an according clearly stating measuring- and control-system will make the behaviour of the dam understandable to us and report alterations at the building early enough.

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