Consequences of the phenomena of adjustment and transport of mineral grains within filters and drainage systems

Conséquences de réajustement et de transports des grains minéraux sur l'aptitude de fonctionnement des filtres et des systèmes de drainage

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ABSTRACT: The paper deals with the phenomena, which lead to the transport of mineral grain (suffosion) and to adjustment of mineral grain caused by structural changes in porous media. The probability for the appearence of mineral grain being transported and adjusted will be assessed. Both processes are mainly based on hydraulic reasons and may have an important influence on the functionality of drainage systems and filters. In case of conditions being unfavourable the constructions may totally loose their serviceability. Based on this paper the authors want to give criteria of assessment to civil engineers. Within these criteria the probability of failure for numerous combinations of mineral soil-filter-systems in dependence on the chosen construction including the geocomposite with drainage function can be estimated.

RESUME: La contribution s'occupe avec le phénomène qui mène au transport des grains en substance poreuses et qui cause un rèajustement des grains en conséquence du changement des structures. La probabilité du transport des grains et du réajustement des grains est examinée. Il est possible que l'art de fonctionnement des drainages par drains et des filtres est influencé déterminant par les deux procès només qui de leur coté sont dépandant des conditions hydrauliques. Quand les conditions sont défavorable le fonctionnement des drainages par drains et des filtres peut être perdu totalement. Avec cette contribution les auteurs veulent donner un instrument d'estimation. Pour l'ingenieur il sera possible d'estimer la probabilité de raté des combinations nombreuses de sol et de filtre. Laquelle est dépandant de la construction choisie et des structures des drainages par drains qu'on a préféré à cause des circonstances géosynthetiques.

1 INTRODUCTION

During the process of water discharging out of a mineral soil (basis-mineral-soil) into a drain, the phenomena of adjustment and the transport of mineral grain has to be prevented in the interface basis-mineral-soil ↔ filter. The basis of building long-term functionable and reliable systems is a comprehensive knowledge according to the phenomena of adjustment of mineral grains and it's mechanisms of effect.

It's essential that each of these mechanisms and it's consequences can be evaluated as positiv or negativ for the system's functionallity. The colmation of filters respectively the siltation of drains may have very negative consequences for a construction. Under different marginal conditions a colmation may like to be wanted from the early beginning of planning phase e. g. installing a filter to colmate it with grain particles and the forces of the seepage-water.

2 MECHANISMS OF EFFECT AND CONSEQUENCES

2.1 *Mechanisms of effect*

The description of the upper mentioned mechanisms of effect can be reached with a subdivision into different characters of behaviour respectively appearing processes. Processes of suffosion and erosion as well as other phenomena of adjustment of mineral grains can be global mentioned.

The term suffosion means the adjustment and transport of finer frictions of a basis-mineral-soil through the pore-area. The structure of the mineral soil still remains.

Processes of erosion are to be characterized with the adjustment and transport of nearly all frictions of a basis-mineral-soil at it's surface and/or it's interior initiated by the forces of surface- or seepage-water. The phenomena of erosion may probably appear at the interface of a flown through earth body; prerequisite, the size of the pores of the bordering on soil allowes the admission and hiking through of eroded grain-particles. Erosion processes may also occure at the interface of mineral soils and massive structures.

In case of adjustment of mineral grains -separation- local breakdowns of all grain frictions in available cavities may appear. Talking of non or less-cohesive soils the mentioned breakdowns mainly occure in case of water saturation which leads to the loss of apparent cohesion. The events appear suddenly with a turbulence of the local destroyed soil structure and the more or less intensive separation of different frictions of the mineral-basis-soil.

The mechanisms of effect in case of adjustment and/or transport of mineral grains are influenced by the following marginal conditions:

- Flow direction of the groundwater
- Changes of the flow direction
- Seepage pressure on soil structures, individual mineral grains, eventually groups of grain frictions -hydraulic gradient-
- Grain-size distribution of the mineral-basis-soil according to suffosive grain fricitions
- Pore distribution of the mineral medium according to general pore channels
- Presence of non-stable cavities in case of hydraulic stresses
- Chemistry of the basis-mineral-soil in front of the filter- respectively the drainage-element.

2.2 *Consequences of the appearing mechanisms*

As a result of the mechanisms colmation-processes, depositions of mineral grains, ockre formation and precipitation of lime as well as the formation of new cavities can be observed.

Processes of colmation are to be described with a deposition of fine-grained mineral particles transported by the seepage water to the surface or into the pore area of a porous mineral medium. The deposition of fine sized mineral grains transported by the seepage water requires the process of suffosion in another area of the earth body.

Depositions of fine grained particles may occure in artificial or natural cavities of the flown through cross section and lead e. g. to the siltation of drains.

Ockre formation and precipitation of lime, that means biochemical sedimantation of iron and lime may appear in areas

where water flows out of a homogenous porous medium. The outlet of the water leads to a change of the circulation respectively the percolation. The ventilation of the seepage water is playing an important rule within the evaporation.

The formation of new cavities in the porous medium may lead to recent structural destructions e. g. backward erosion.

The kind of consequences for long term functionallity of the construction can be very different. Examples in geotechnical practice show that the failure of filters in front of drains and/or the complete drainage system may cause a total loss of serviceability of the construction e. g. dam filling in highway construction.

2.3 *Failures and manners of appearance*

The failure of filters in front of drains and/or the complete drainage system can be observed in different manners of appearance e. g.:

- the inadmissible moisture penetration of structures,
- the inadmissible moisture of the natural subsoil including frost damages during periods of coldness,
- the slide of embankments caused by inadmissible seepage forces respectively the unintentional discharge of seepage water at the slope surfaces,
- the loss of bearing capacity of highways caused by moisture penetration including frost damages during periods of coldness,
- the failure of building pits, dams and dykes caused by inadmissible hydraulic forces and seepage pressure.

3 CRITERIONS OF EVALUATION

3.1 *Introduction*

An assessment according to the mechanisms of effect and the probability of their appearance can only be reached by an analysis of the specific object with it's own circumstances and marginal conditions. The basis of this analysis is the determination of the parameters compiled as follows:

- Basis-mineral-soil non-cohesive: Determination of the grain-size distribution, in case of doubt determination of consistency too;
- Basis-mineral-soil cohesive: Determination of consistency, in case of doubt determination of the grain-size distribution required too;
- Determination of the coefficient of permeability in case of soils being surface layers above area-drains e. g. investigation of soil samples with proctor compactation tests or field-infiltration-tests;
- Investigation of the middle and maximum groundwater level;
- Examination of goundwater's chemistry;
- Investigation of the flow-direction of the groundwater and thus the flow-direction towards the drain;
- Determination of the functional requirements and the necessary efficiency of the drainage system.

The results of the upper described analysis according to the specific circumstances and marginal conditions enable to:

- Select/design the filter and/or drain-material, that means determination of the required grain-size distribution in case of mineral filters and drainage systems respectively the required geotextile opening size within geotextile filter-elements and the drain capacity of geosynthetic drain materials
- Assess the necessity and number of planning manholes etc. within the drainage system,
- Assess the necessity to protect the drainage system being ventilated to avoid ockre formation and precipitation of lime.

An evaluation according to the specific mechanisms of effect -the process of suffosion, the process of ersoion, the adjustment of mineral grains and the occurence of ockre formation and precipitation of lime- can be reached on principle by dealing with the criteria/procedures in chapters 3.2 - 3.5.

3.2 *Assessment to the process of suffosion*

To evaluate the danger of suffosion the relevant literature offers several methods e. g. Ziems (1967). The methods' estimation according to the danger of suffosion is based on geometric criteria.

With regard to an evaluation of suffosion processes based on hydraulic criteria only a few procedures are available.

No suffosion processes can be observed on principle in case of:

- A basis-mineral-soil having a consistency of $w_P > 5$ % which can be detected with standard soil-mechanic testing methods
- The hydraulic gradient of the seepage water in dependence on the coefficient of uniformity guaranties the following requirements: $i \leq 0{,}2$ in case of $C_U \leq 20$ and $i \leq 0{,}1$ in case of $C_U > 20$.

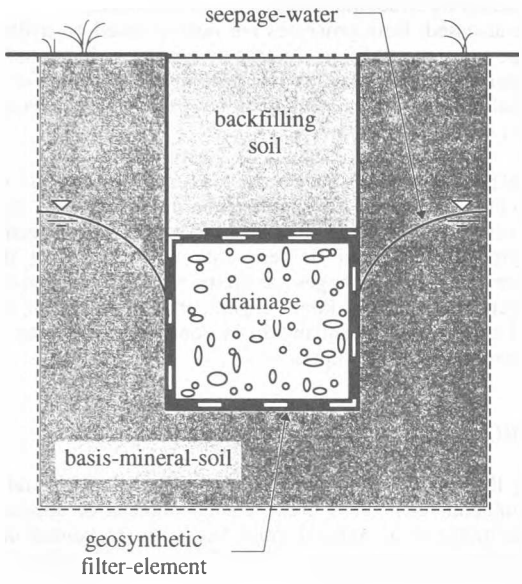


Figure 1. Drainage-trench in highway construction

In case of a drainage system e. g. a highway drainage system like the system shown in figure 1, with a mainly horizontal flow direction of the seepage water towards the drain nearly no significant influences on the system's serviceability can be observed. The reason for this circumstance is based on the rapid reduction of the hydraulic gradient with an increase of the distance to the drain; precondition: The amount of suffosive mineral grain in the basis-mineral-soil does not exceed 5 mass-percent.

3.3 *Evaluation on processes of erosion*

Dealing with the danger of erosion the relevant literature offers many acknowledged checking processes e. g. the leaflet MAG of the BAW Karlsruhe, 1993, leaflet DVWK-221/1992, recommendations P 92-80 of VNIIG 1981 and others.

In case of placing a mineral grain filter the danger of separation has to be taken into account for a coefficient of uniformity $C_U > 20$.

For many years now the installation of geosynthetic filter-elements is an acknowledged alternative instead of placing only mineral materials. The big advantage of these products is their nearly climatic independent placement on the building site and the mostly lower costs.

While installing geosynthetic filter-elements it's especially important that:

- There's no parallel seepage circulation in the interface between the basis-mineral-soil and the geosynthetic filter-element (particularly within the discharge of seepage water

at the surface of embankments),

- A construction quality control exists on the building-site which guaranties for instance, that the filter-elements are not damaged during the installation.

The design criteria for geosynthetic filter-elements used to protect a basis-mineral-soil from processes of erosion should meet the following principle: Structural design as correct and exact as necessary but as simple as possible. Therefore the authors are of the opinion that available design criteria should be reviewed critically and simplified for the most cases of application. The simplified criteria should refer to specific applications and could probably be developed by dealing with the german DIN 18196.

Corresponding to the available state of knowledge an examination from the point of view of soil mechanics has to be performed wether the geosynthetic filter-element should protect a cohesive or a non-cohesive basis-mineral-soil.

In case of a cohesive basis-mineral-soil the examination of the plasticity is sufficient for a simplified design and no further parameters are required.

For a non-cohesive basis-mineral-soil the grain-size distribution and it's coefficient of uniformity has to be analysed. The simplified design could be reached by comparing the geotextile's opening size with the corresponding particle-sizes of the basis-mineral-soil.

3.4 *Adjustment of mineral grain particles*

Adjustments of mineral grain particles mainly occure while placing geosynthetic filter-elements on a non-horizontal base or subgrade level. In the very most cases of these applications cavities remain in the interface between the basis-mineral-soil and the geosynthetic filter-element after the installation. Intimate Conatct between both materials (basis-mineral-soil and geosynthetic filter) can not be guaranteed all over the whole interface as shown in figure 2. The cavities collapse when the groundwater level/the seepage line increases, adjustments of mineral grains take place and lead to conditional separations. A new situation of contact between the geosynthetic filter and the basis-mineral-soil happens and has not be taken into account while modelling the system's marginal conditions. Cavities appear because of geosynthetic material's tensile strength. This material property prevents the geosynthetic filter being in Intimate Contact with the basis-mineral-soil a not really plane subgrade level.

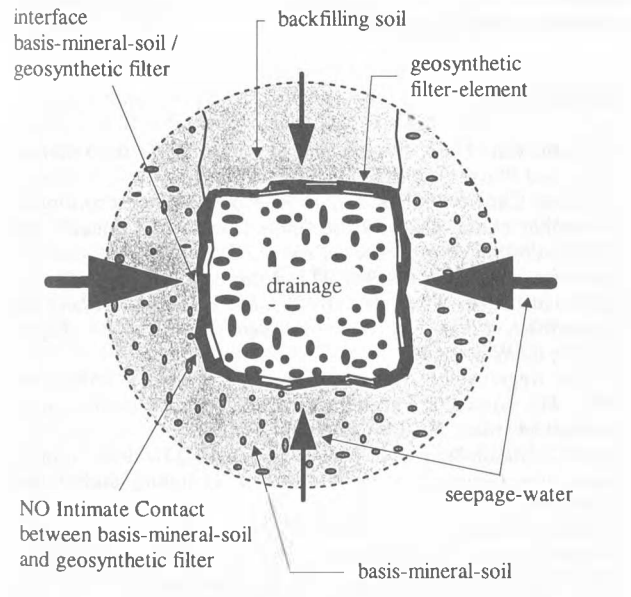


Figure 2. Deatil according to the situation of contact between geosynthetic filter and mineral-basis-soil

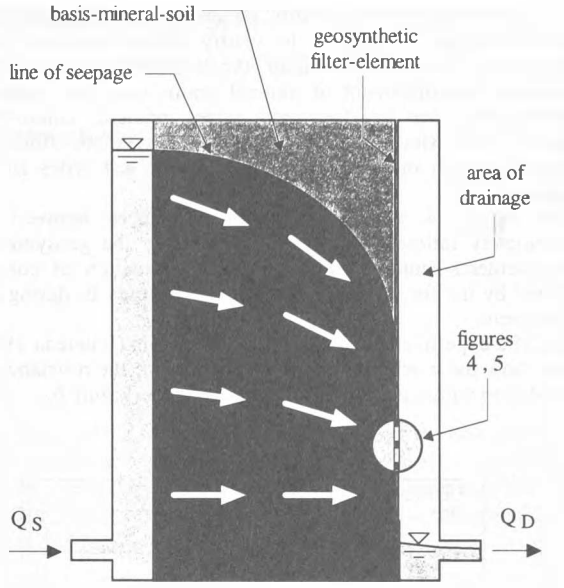


Figure 3. Modelling of the situation of contact „in-situ" in the laboratory

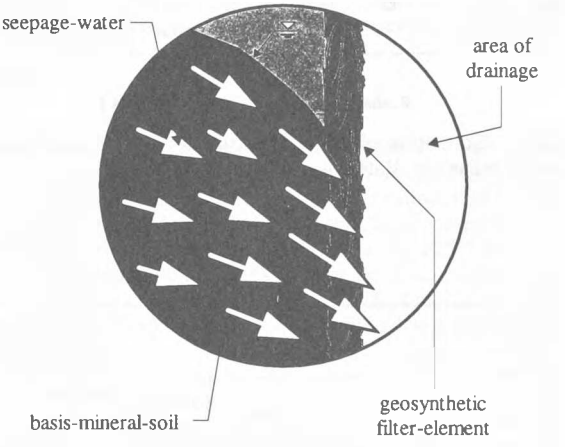


Figure 4. Study a) Intimate Contact between basis-mineral-soil and geosynthetic filter-element after installation

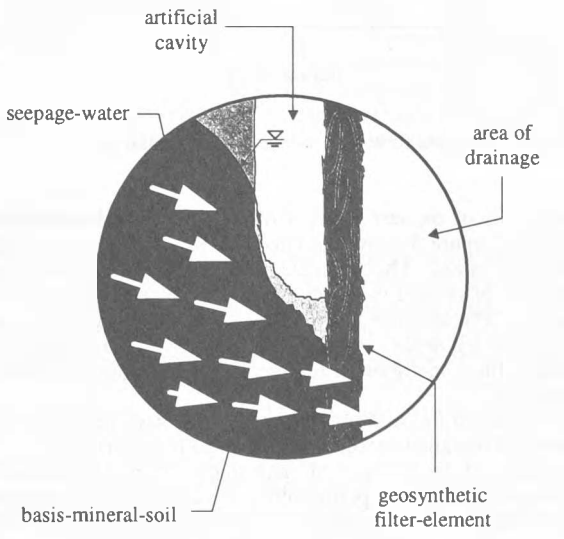


Figure 5. Study b) Intimate Contact between basis-mineral-soil and geosynthetic filter-element caused by the forces of the seepage-water

A model to simulate the „in-situ" conditions in a laboratory has been developed -figure 3- to clarify the problems of the phenomena of contact. Within the carried out test series influences of adjustment of mineral grains onto the system's functionallity can be measured under realistic conditions. General conclusions for the design of geosynthetic filters in connection with the detailed analysis of the test series are in preparation.

The figures 4 and 5 show the differences between an immediately Intimate Contact after installing the geosynthetic filter-elements (study a) and the special situation of contact reached by the forces of the seepage water (study b) during the experiment.

Specific experiments with single grained soils (Batereau 1981) show, how the blocking of pores may influence the resistance of perculation within geosynthetic filter-elements (Figure 6).

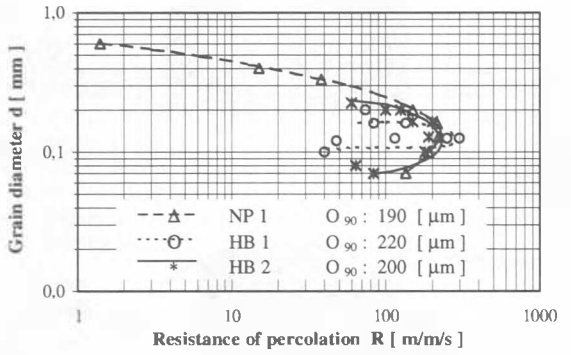
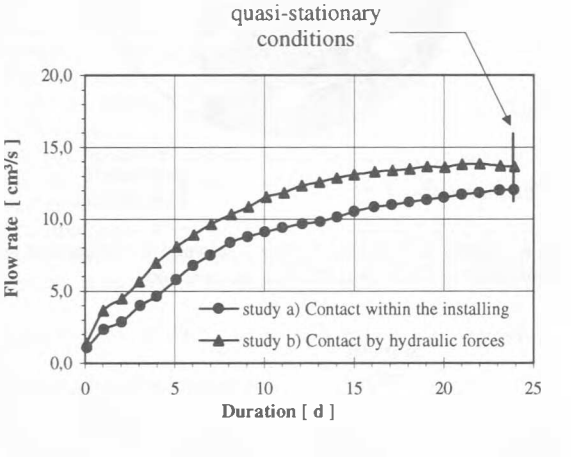


Figure 6. Colmation of three-dimensional geosynthetics caused by sandy materials. Batereau (1981)



Figur 7. Absolute flow-rate in test-studies a) and b)

The results of the test series with the schematic presented test system of figure 3 show the consequences of jetting processes into pore areas. The absolute flow rate with the different situations of contact in the studies a) and b) can be taken out of figure 7. The absolute flow rates of figure 7 can be assessed qualitively by dealing with the corresponding positions of the seepage lines in figure 8 for the so called „quasi-stationary" conditions.

According to figure 8 an only reduced drainage per square-unit within the marginal conditions of study b) is reached.

Because of the danger of adjustment of mineral grains a maximum decrease of permeability = increase of the resistance of percolation in the interface geosynthetic filter ↔ basis-mineral-soil (in opposite to the none with mineral soil influenced geosynthetic filter-element) can be estimated with a factor of one hundred.

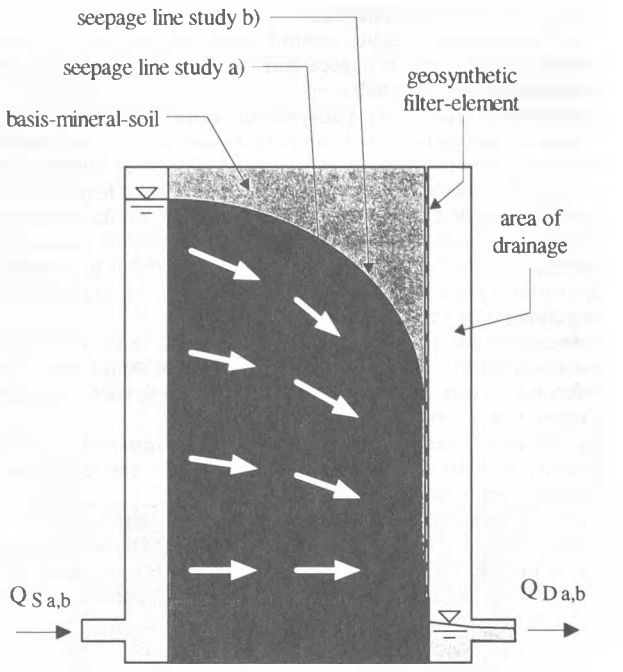


Figure 8. Quality of seepage lines for the test studies a) und b) under quasi-staionary conditions

3.5 *Processes of ockre formation and precipitation of lime*

The problem area of ockre formation and precipitation of lime shall not be discussed in detail here. To evaluate these processes and their accompanying consequences for the system's serviceability e. g. the recommendations of the german DVGW W 131 can give further information.

4 CONCLUSIONS

According to the available state of knowledge it can be estimated that a reliable design of geosynthetic filter-elements is possible by taking into account the mentioned mechansims of effect and their consequences for the system's serviceability.

Therefore the aim of further activities will be to simplify current filter criteria especially within the application of geosynthetic filter-elements.

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