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Ten years of experience with fully vegetated retaining walls using geotextile reinforced earth material

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ABSTRACT: A considerable amount of time has passed since the first geotextile reinforced structure using a complete, practical and proven solution. Over the past 10 years the following considerations habe proven their importance: Clear view of the statical aspects, use of adapted geosynthetics, simple practical solutions for the construction, serious considerations for a good vegetation cover including longterm maintainance.The different aspects are demonstrated in the context of a large noise bund along the highway N1 near St.Gallen in Switzerland. The height of the bund measures beetween 4 m and 8 m, the project length reaches 1.1 km and the total vertical face area is around 12'000 m².

1 INTRODUCTION

In the last few years the market for geotextile reinforced structures has grown significantly. The search for more cost - effective solutions has led to a wide range of technical systems. Few of them can fulfill most or all of the different requirements for a good end result.
Ten years of direct experience and the design of hundreds of projects allow a good judgment of the major requirements.

2 REQUIREMENTS

Contrary to a common approach, a few basic aspects have a major influence on the final quality of construction. None of them is related to a simpler or more sophisticated design method.

2.1 Internal and External Stability

The internal stability is determined mostly by some kind of wedge system [1]. Simple mechanisms will do. They should simulate the known actual deformation behaviour and simplify them.
In our experience a modified two wedge mechanism (fig. 1) gives consistent results for a wide range of influencing parameters [2], [3], [4]. A major aspect is the consideration of the stiffening influence of the geotextile layers. Many other mechanisms completely neglect any stiffening effect.

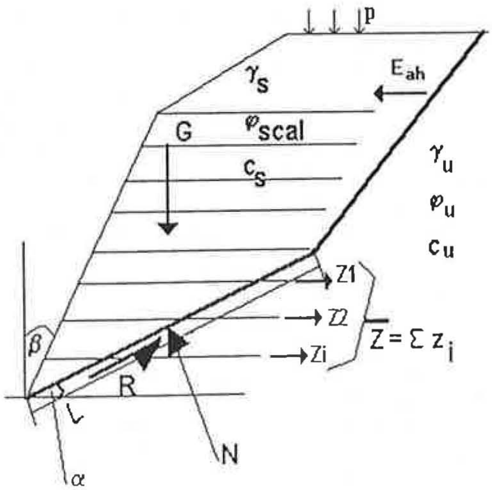


Figure 1: modified two wedge mechanism (STRU)

The verification of the external Stability (fig. 2) is often neglected as a lot of promoters do not consider this aspect at all or only in rudimentary degree. In reality many damages of different kind are related to the external stability.
For the determination of the external stability a large number of methods and computer programs can be used. Most of the methods are based on the

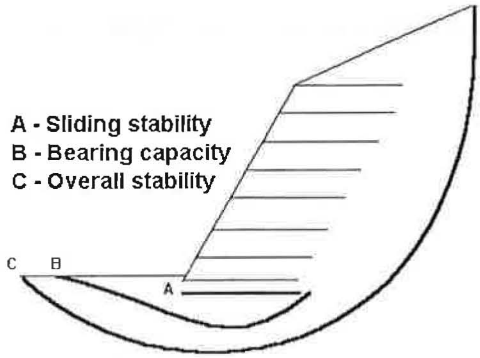


Figure 2: Stability analyses

determination of the stability of a sliced earth body. Because nearly all of them are not considering the stiffening effect of the reinforced soil body, the safety results stay on the safe side. A suitable calculation requires a deeper knowledge in soil mechanics.

2.2 Interaction Soil - Reinforcement

The forces have to be transfered from the fill material to the geosynthetic and vice versa. This aspect is often considered using a reduced friction angle between soil and geotextile. It is mostly forgotten that the actual combination of soil type and the type of geosynthetic is essential. A gravel has a high friction ratio with a geogrid but the ratio can be rather low with a fine grained soil. A good overall value can be achieved with a mechanically stabilized nonwoven. For fine soil the texture is essential whereas for coarse soil the macro flexibility guarantees a good transfer of the forces.

The interaction soil - reinforcing element also determines the deformation of a wall. The deformation is always smaller than could be expected by testing the reinforcing elements [5], [6], [7]. There are basically two reasons: The forces are mainly taken by the stiffer element which is in this case the soil; the embeded geosysthetic itself gets a more or less reduced deformation potential. Deformation problems in a geotextile reinforced wall are hardly related to the actual deformation behaviour of the reinforcing element.

2.3 Build - Up Procedures

By far the most important point for the final quality of a geotextile-reinforced structure is the actual building procedure. The essential terms in this context are: compaction, consolidation, water content, soil type.

Compaction:
Good compaction is essential, but it is seldom easy to reach. Mistakes in the preparation work for the fill procedure in many cases lead to problem which cannot easily be rectified.

Consolidation:
The consolidation process is roughly proportional to the third potence of the drain length. As often large reinforced soil bodys are built using fine fill, the longterm pore pressure can be a major destabilizing factor.By the use of appropriate systems, e.g. draining non woven reinforcing elements, consolidation process can be sped up to a large extent.

Water content:
The aspect of the consolidation is important in connection with the water content of the fill. Depending on the climate and the geological conditions the care for the fill material in connection with rainfall is a major duty for the contractor. To keep the fill compactable it is often necessary to stop the actual build up.

Soil type:
Some systems have very incisive restriction on the fill material. In the common case the fill material is more or less given by the local underground conditions. To import the appropriate fill can have a very big influence on the final cost. To have a system with the ability to use a wide range of soil types can save a lot of money.

2.4 Vegetation

As a permanent surface of a wall the geosynthetics alone are in most cases not satifactory. One reason is the actual appearence which commonly can't fulfill an aesthetic criteria [8]. Another reason is the vulnerabilty of the geotextiles or geogrids to mechanical damages. More important is the permanent exposure to the sun and weathering. Even resistent geosynthetics are seriously influenced and will change their characteristics.

Beside any kind of hard facing a vegetation layer can meet the different requirements for protection and aesthetics. To be able to establish a good vegetation cover different aspects have to be considered:

Protection:
Best protection of the geosynthetic can be reached, when beside the vegetation layer itself a protecting medium is applied. This can be reached by a specially designed organic germination layer sprayed on the surface of the wall.

Surface:
Depending on aspect and rainfall a surface should never be steeper then 60° or 70°. Steeper surfaces need in general permanent watering. The actual surface has to be more or less even. Overbowing parts will reduce the vegetation to stripes.
Penetration:
The geosynthetic in the front has to meet completely different requirements. In the first instance erosion control; it is important not to lose the fine material directly behind the surface. In the long term the behaviour for the penetration of the roots is crucial for the vegetation layer. The openings have to be flexible enough when the roots get larger.
Topsoil:
To establish a complete and lasting vegetation it is necessary to have a layer of topsoil or at least a fine silty material behind the front. A vegetated slope can't be built purely considering friction angle and compaction quality.

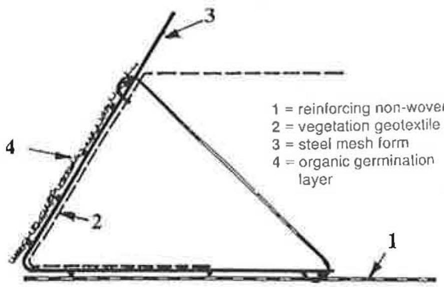


Figure 3: Surface design of the Textomur®-System

2.5 Maintainance

A wall and especially a vegetated one has to be maintained after construction. Depending on the kind of surface and vegetation layer maintainance can be easy, difficult and even nearly impossible. Again different aspects influence the ease of maintainance:

- type and quality of vegetation
- flatness of the surface
- sensitivity of the front to mechanical damage
- suitabilty for use of machines

2.6 Longterm Stability

The actual lifetime of a structure is determined by the combination of all previously indicated aspects. With a good system, high quality construction, a really covering vegetation layer and an adapted maintainance the real lifetime will be on a similar level as any construction in concrete or steel.

3 NOISE BUND NEAR ST.GALLEN

3.1 Starting Point

The existing highway N1 from Zurich to St.Gallen in the northeast of Switzerland is passing Gossau, a suburb of St.Gallen on an embankement directly along a heavy populated residential aerea. The noise level was surpassing the legal regulation so that measures had to be taken.
The highway embankement is visible from a large area. Therefore the aesthetic aspect of any noise protecting measure had a major influence on the chosen system. Beside other aspects this was one of the main reasons to choose the Textomur®-System (fig. 3,4) which has a proven track record on the market for over 10 years.

3.2 Project Description

The existing highway embankement has a slope inclination of 1 : 2 and a maximum height of 25 m. The actual safety of the embankement was varying as during the site investigations poorly compacted zones and local elevated porewater pressure were determined.

Figure 4: The finished noise bund

The project zone has a total length of 2.2 km. On a length of 1.1 m the Texotmur®-System was used. The general section (fig. 5) shows the inclination of 60° and a height of 4 m towards the highway and 8 m towards the residential area. The total vertical face area of geotextile reinforced structure is about 12'000 m².

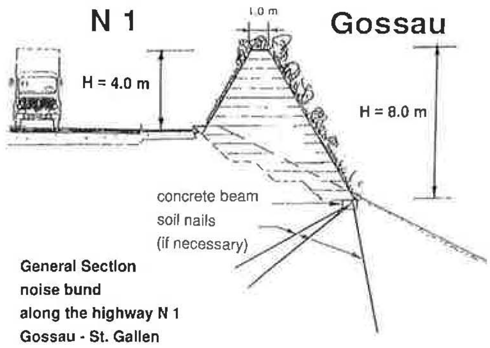


Figure 5: General Section

3.3 Soil Characteristics

For the construction ordinary excavation material was used (fig. 6). Minimal values for the friction angle and maximum values for the water content were given. As dumping of excavation material is expensive the re-use of a dug fill was welcome and led to a major cost saving.

3.4 Reinforcing Elements

As most of the fill was not purely granular but had normally a rather high fine content, consolidation or possible elevated pore pressures were a major concern. By the use of the special anisotropic nonwoven reinforcing fabric a draining element on each layer of 0.5 m could be realised.
The needle punched fabric has a minimal rupture strength of 40 kN/m and consists of polypropylene (tab. 1). Polypropylene is resistent to elevated pH values since a stabilization with lime was nessesary.

Tab. 1 Properties of the reinforcing nonwoven

Tensile strength	40 kN/m'
Extension at max. load	120 %
Working load	10 kN/m'
Safety factor F_G	2.0
Calculation load	5 kN/m'
Creep elongation	
100 h to 10'000h for load 5 kN/m'	2 %
100 h to 120 years (extrapolated)	4 %

A common concern about using nonwovens as reinforcing elements is the low deformation modulus when tested in the laboratory. However measurements for this and other projects [5],[6] show minor deformations during construction and shortly afterwards when the final consolidation process takes place. Longterm deformations are very

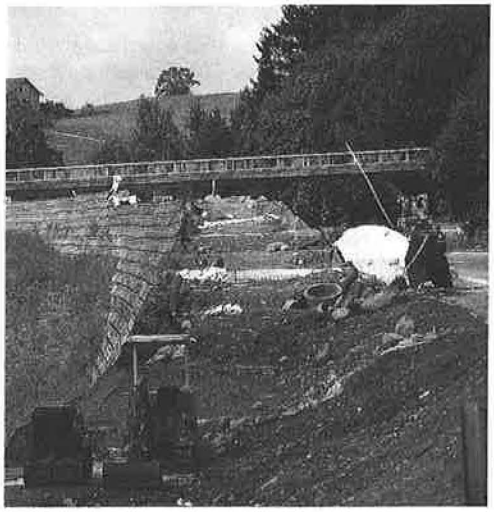


Figure 6: View of different reinforcing layers

small and are not exceeding values of constructions with much stiffer reinforcing elements.

3.5 Internal and External Stability

The Internal Stability was determined by the specially developed computer program of the System. It works normally with a modified two wedge mechanism, which for the case of an embankement is simplified to a one wedge mechanism (fig. 7).

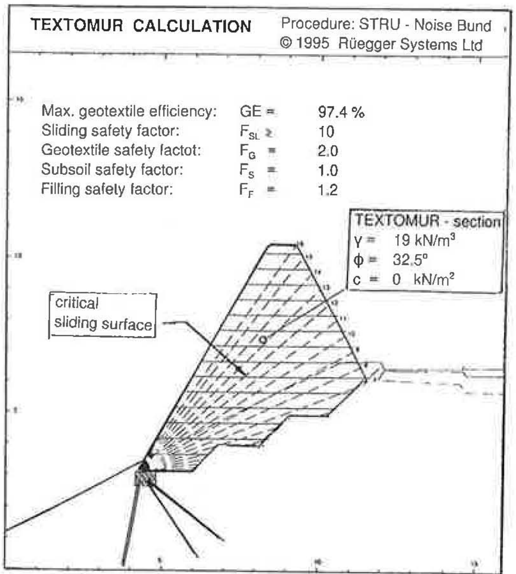


Figure 7: Internal Stability (computer calculation)

The overall stability was determined by a large number of slip mechanisms. In some places with a low quality fill the safety was not sufficient. To reach the necessary safety level a concrete beam along the construction foot was planned which is held back by the necessary number of soil nails.

3.6 Actual Construction

The actual construction took place in 1994. Even with a lot of bad weather with heavy rainfall the project was nearly completeted by the end of the year.

The application of the special germination layer and the seeding was partly done in 1994 and the rest in spring 1995.

3.7 Special Experiences

The bund was completed according to the schedule. No deformation problems were noted for the noise bund nor for the existing embankement which was monitored by a series of inclinometers.

After some smaller starting problems the contractor was satisfied with the handling of the system parts and the general work progress.

4 TEN YEARS OF EXPERIENCE

The experience of ten years of practical work with one system for reinforced soil structures and the observation of the market with a lot of new other solutions show some basic results.

4.1 Internal Stability

The internal stability is rarely a problem when:

- the compaction is sufficient
- the system allows compaction right to the front
- the consolidation of the fill is guaranteed
- the front angle is not exceeding 70°

The necessary amount of reinforcing is important however always strongly related to the mentioned points and especially to the actual friction angle of the fill.

4.2 External Stability

Often the general stability aspects are neglected. A geotextile reinforced soil body is always a heavy element and therefore can endanger the overall stability and the bearing capacity of the underground.

All projects built in a slope or over poor quality underground should be accompanied by an experienced geotechnical engineer.

4.3 Vegetation Behaviour

The importance of the vegetation is often underestimated in the beginning by the engineer, by the contractor and also by the client.

After the completion of the project this aspect gets more and more important. A poor quality of the vegetation is always visible.

Poor quality of the vegetation has different main reasons:

- inadequate front system
- front angle too steep
- poor quality of vegetation layer and seeding
- unfavorable fill (not enough fines)
- wrong maintainance

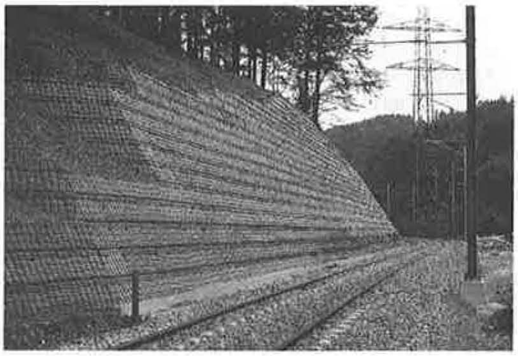
4.4 Maintainance

Maintainance is necessary in the first years as the fast growing grass, needed for the first greening cover, has to be cut. With time (after 2 or 3 years) maintainance can be reduced to a large amount; the vegetation will adapt itself to the local conditions. The even surface of the Textomur®-System allows the mechanical cut of the grass (fig. 8)

In the long run, one or two cuttings per year will be sufficient, which is very much comparable to any grassed slope. In remote places the maintainance cycle can be lifted to several years.

Fig. 9 and 10 show a Textomur®- construction just finished und the appearance over five years later.

Figure 8: mechanical cut



Figures 9,10: Textomur® raw and vegetated

5 OUTLOOK

In the last five to ten years the vegetated retaining systems using geosynthetics as reinforcement have taken a relevant share in the market.
The growing economic importance has led to a large number of new systems. Many of them are only focused on material savings and neglect the aspect of quality and practicality. A lot of them will disappear after a short while.

With time, only those systems able to address all aspects from the static analysis, through competent construction methods to quality vegetation with minimal long term maintenance will remain.

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