GEOSYNTHETIC REINFORCED RETAINING STRUCTURES IN ALPINE REGIONS

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Abstract: Any civil constructions in alpine regions require special measures with regard to design, execution and construction materials and methods. Especially for retaining structures aspects of safety, construction cost and availability of materials are of decisive importance as well as the limited time available for construction. All these factors play an important role in design and execution.

Two examples serve to show how the use of adequate Geosynthetics leads to an economically and technically optimum solution for such Geosynthetic reinforced retaining structures.

1. High water amount and heavy traffic destabilised a road in the mountains of Styria/Austria. The Styrian Government was in hurry to find a fix but the budget was limited. First thoughts were dealing with a 100 m long bridge with assumed costs of 0.9 million €. The alternative of a retaining wall was initially not an option because of the needed level difference of 34 m. It became clear that the technical solution of a Geosynthetic reinforced steep slope was possible and construction time and costs could be reduced to more than half. The requirements of this construction concerning ultimate and serviceability limit states could be solved by using adequate construction materials in combination with proper construction equipment and staff. After less than 50 days construction time the retaining structure with 34 m height, 100 m length and an inclination of 65° at the front was carried out.

2. The second example shows a 640 m long and up to 26.5 m high protection bund by reinforced earth, protecting a village in the Tyrolean Alps against avalanches. In recent years these natural disasters led to negative headlines for Austrian winter tourism, therefore the Government is anxious to protect susceptible areas. The method of Geosynthetic reinforced slopes gives a new possibility in natural looking protective systems.

Keywords: geosynthetic, reinforced earth, embankment, construction

EXAMPLE 1 – GEOSYNTHETIC REINFORCED STEEP SLOPE

INTRODUCTION

Due to major seepage problems and increased traffic loading, the B115 highway in the mountains of Styria/Austria was in danger of slippage. The Government of Styria was under time pressure to find a technically viable solution to the problem whilst keeping within a limited budget. The highway is mainly used by heavy trucks from timber industry, and this usage had had to be curtailed after massive deformation of the road over an old, unstable stone wall (10 m height).

The first solution proposed was a 100 m long bridge with assumed costs of 0.9 million €. The alternative of a retaining wall seemed at first not to be an option because of the required difference in levels of 34 m. However, on checking a solution with geosynthetic-reinforced earth, it became clear that a technically viable solution was possible, and that construction time and costs could be cut in half.

It would be possible to address the technical requirements of the construction with regards to ultimate and serviceability limit states (deformations, settlements) by using appropriate materials in combination with proper construction equipment and trained personnel.

Optical aspects – a natural looking, vegetated front face – also had to be considered in the design.

After less than 50 days construction time the geosynthetic-reinforced retaining structure with a height of 34 m, a length of 100 m, and a front slope of 65° was built.

The cost, originally estimated as 560 k€, was kept to 410 k€; this represents a cost reduction compared to the proposed bridge of 54%.

Figure 1. Situation of damaged road

DISCUSSED STRUCTURAL SOLUTIONS

Bridge design

The design of a 100 m-long bridge with 5 spans to overcome the problems described had already been under discussion for more than 10 years. The foundations of the abutments and the single pillars in the alpine surrounding were the major cost factors in this solution. Calculated costs of about 900 k€ were the benchmark for alternative technical solutions.

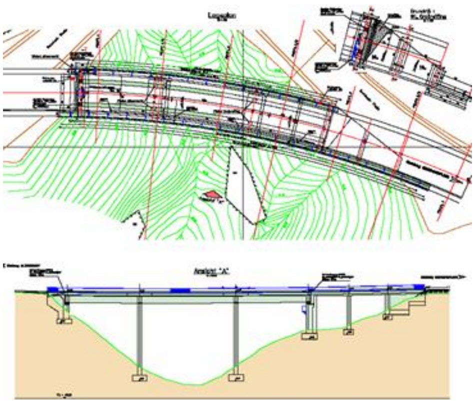

Figure 2. Plan view and longitudinal section of the bridge

Alternative design with geosynthetic reinforced earth

The B115 highway is routed along the Alps, which means that any horizontal change of road alignment away from the mountain requires a very high retaining structure. Conventional gravity retaining structures were not feasible for the given project. Mechanical stabilized earth with the possibility of a natural facing system was selected to be investigated in details as a possible alternative.

The request of a vegetated, natural-looking surface was a decisive parameter for the geometry of the structure. Experience in the local climate limits the inclination of vegetated steep slopes without additional irrigation to a maximum of 65°.

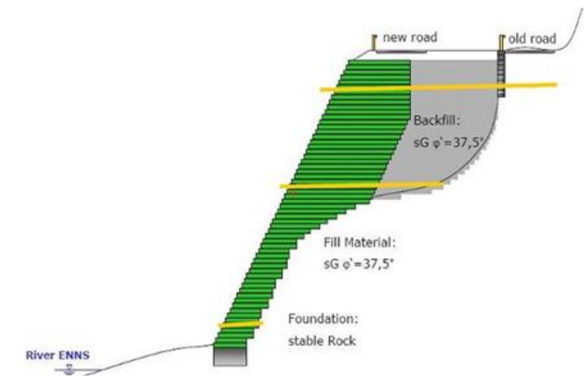

Figure 3. Cross section of geosynthetic reinforced steep slope

This slope angle, together with the alignment of the new road, determined the requirement for a 34 m-high retaining structure. Additionally, the maximum embedded length of the different reinforcement layers was partly limited by the geometry of the foundation rock.

DESIGN AND SLOPE SYSTEM

Geotechnical design

The slope was designed in accordance with the German recommendations for geosynthetic-reinforced structures EBGEO (1997). The internal stability was calculated using limit-equilibrium analysis. With regard to the geosynthetics, two cases had to be investigated:

- Pullout of the reinforcing layer (calculation of the reinforcement length)
- Rupture of the reinforcement layer (calculation of the ultimate tensile strength)

The external stability was calculated with regard to Austrian standards for slope failure (ÖNORM B 4433), base failure (ÖNORM B 4432) and permissible earth pressure on the facing (ÖNORM B 4434).

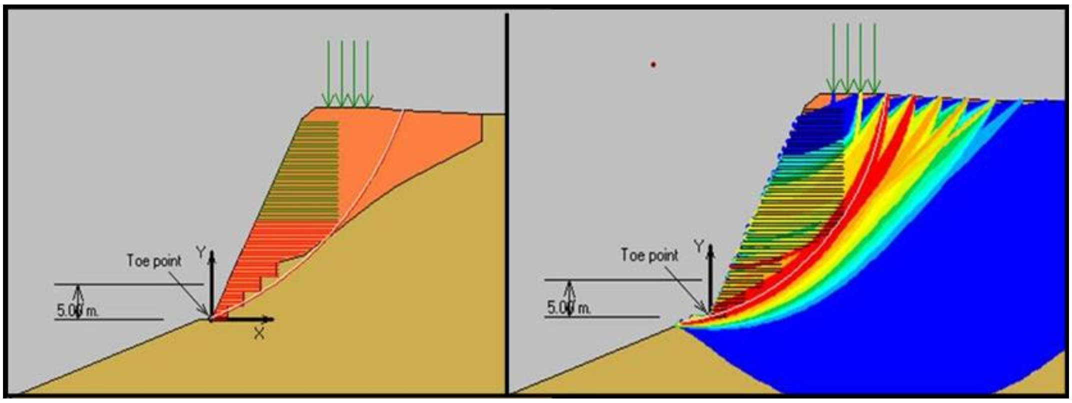

Figure 4. Critical failure circle and safety map of the structure

The stability requirements were ensured by layers of geogrid with different tensile strengths ranging from 100 kN/m to 200 kN/m. The geogrids used are products consisting of high-tenacity polyester yarns with a polymeric coating.

Equally important was the quality requirement on the fill and backfill material. Here, a minimum internal friction angle of φ' = 37.5° and a Proctor density of $D_{PR} \geq 98\%$ were specified.

System for reinforced steep slope

The system used incorporates geosynthetic reinforcement, prefabricated steel-mesh shuttering elements and an erosion-protection grid.

Geosynthetic reinforcement

A high-strength geogrid made of polyester yarns with a polymeric protective coating was used; the design called for tensile strengths of 100 kN/m and 200 kN/m.

The flexible nature of the geogrid used facilitates simple installation and allows the geosynthetic to develop an intimate contact with the structural fill, thus creating an effective frictional interaction.

Steel shuttering

Pre-fabricated steel mesh elements bent to the required angle were used as sacrificial shuttering. This guaranteed that the slope could be constructed in exact accordance with the design. The relatively flexible nature of the facing elements permits subsequent settlements of the fill without creating problems with deformation of the slope surface. Protection against corrosion is not required, as after completion of the construction and any associated settlements, the shuttering elements fulfil no further stabilising function.

Erosion-protection grid

The system is completed by an erosion-protection grid made of glass fibres. During the construction stage, and until vegetation has established, it protects the slope surface from erosion and facilitates permanent vegetation. On a long-term basis, the grid provides local slope stability of the surface. Important parameters are therefore UV and chemical resistance, low flammability and adequate tensile strength. On one hand the mesh size chosen minimizes surface erosion, and on the other hand supports the free growth of vegetation.

Fill material

A high-quality fill material with good compaction properties and high shear resistance was used for fill and backfill. Additionally, good-quality topsoil with adequate water-storage capacity was installed along the slope surface to allow complete and permanent vegetation. It was installed with a thickness of 0.3 – 0.5 m at the front face.

CONSTRUCTION OF THE RETAINING STRUCTURE

Foundation works

Normally these types of structure are directly founded on natural soil with adequate bearing capacity. In such cases, the foundation soil has to be graded and compacted. In the project described here, it was not possible to create a graded foundation area, so initially a concrete block had to be installed in the rock base.

Drainage works

Significant quantities of water seeping out of and along the rocks had led to the failure of the old stone wall, so drainage measures were of major importance. Collecting water on the contact zone rock / fill was done in two ways. In the lower parts of the slope a geosynthetic drainage composite was used to collect and remove seepage and rock water. In higher parts drainage gravel was used. The water was then collected in drainage pipes which were led through the reinforced construction to remove water to the outside. Close to the toe point of the retaining structure, the water was discharged into the River Enns.

Figure 5. Foundation and drainage works

Construction procedure

Building a geosynthetic-reinforced retaining structure works step by step. First, the geogrid is placed according to the required reinforcement length, evenly and free of folds and wrinkles. The steel-mesh shuttering elements are then placed, lined with the erosion-protection grid and fixed with restraining hooks.

Then the fill material is placed and compacted in layers with a maximum thickness of 0.3 m to guarantee the compaction requirements. The final step is the placing of the topsoil in the front elements (0.3 – 0.5 m), after which it is compacted and the erosion-protection grid folded back.

The installation of the next layer starts with the placement of the geogrid.

The time required for the construction of any single layer depends heavily on the boundary conditions of the project. The daily output in Rodlau varied widely. At the beginning, with an extremely narrow workspace, only 100 m^3 of fill could be placed per day. After reaching a wall height which allowed the use of a second excavator, the daily output was increased by a factor of 10 to 1.000 m^3 fill/day.

The final site setup is illustrated in Fig. 6.

Figure 6. Site setup

EXAMPLE 2 - PROTECTION BUND

When large volumes of snow or rocks start moving, even woods have practically no influence on the dynamics and/or retaining of the masses. Protective measures against sliding and falling masses can be divided into primary and secondary measures. Primary measures take place on the slope itself, whereas secondary measures, such as retaining walls, dikes and embankments, are used to protect against masses already in motion.

In the case of avalanches, a wood or small forest loses its protection function when the avalanche starts above the wood. The avalanche strikes a path into the wood, resulting in its damage.

Beside supporting and 'braking' structures, deflection structures can be particularly effective in affording downhill protection. Avalanche protection structures (dikes, embankments, walls, galleries etc.) are designed to withstand the forces of the avalanche, with the aim of deviating or splitting the moving masses or restricting their lateral expansion.

Such protection walls can be constructed quickly, easily and cost effectively with Geosynthetics, very often using on-site fill material. High-strength Geosynthetics allow the construction of steeper slopes with higher stability. Furthermore, optically attractive solutions can be provided due to different configurations of the surface of such slopes.

PROTECTION BUND DIASBACHALPE

In the spring of 1991, two avalanches started moving on the Diasbachalpe and merged on their way down to the village of Kappl. Kappl is situated in the Paznauntal in Tyrol/Austria and a famous winter sport area. After this dramatic event the entrance to the Paznauntal was closed for 3 days, just accessible by helicopters.

In order to avoid an event like this in the near future primary protection measures were improved and carried out, such as protection galleries on the endangered slopes. Nevertheless the past 20 years have shown that all these measures are not enough for extraordinary events, which are more and more popping up due to climate changes in the Alps.

In 2004 the design for a protection bund on the foot of the Diasbachalpe started. The protection bund consists of a 5 m high stone foundation and on top of that a geosynthetic-reinforced steep slope with a height of up to 21.5 m.

CONSTRUCTION OF THE RETAINING STRUCTURE

The avalanche protection bund for the Diasbachalpe will have a total length of 640 m and a height of up to 26.5 m. The inclination of the slope, which is orientated to the avalanche, will be 2: 1 (65°) and 2:3 (34°) to the valley.

Foundation works

The first 5 m in height of the bund is constructed with rock blocks, on one hand to give a stable foundation, on the other hand to have enough resistance and permeability to allow the massive water flow coming from the snowmelt passing along the bund.

Geosynthetic reinforced steep slope

The system used for the steep slope on top of the rock blocks is the same as already used in Example 1. Because of the sea level of the site (2000 m above sea) special measures have to be taken to take the vegetation into consideration. Above the timber line regular vegetation will not take place, and this has to be considered for the facing of the steep slope.

Therefore some modifications were discussed on the elements of the facing, like increasing the long term resistance of the steel cages and cooperating with local biological experts to pop up with resistant seed mixtures.

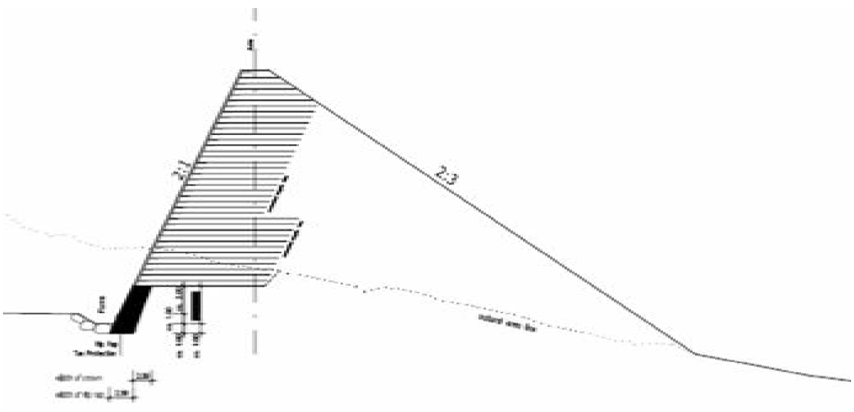

Figure 7. Cross section of the protection bund

Construction procedure

The work on the protection bund started in 2007. Due to weather conditions the window for construction works is from June to September, so in total 4 months a year. The foundation works are finished so far and the first layers of reinforced earth are currently being carried out. In total the bund will be finished in the year 2010.

CONCLUSION

In alpine regions, specific boundary conditions of construction design and execution have to be taken into account. Particularly in the case of retaining structures, aspects of safety, construction cost, and availability of materials are of decisive importance, as is the limited time available for construction.

In the first project presented, a retaining structure had to be built in very difficult, narrow surroundings with limited time and money. The method used for the construction was geosynthetic-reinforced earth. The method came into the project as an alternative solution with predicted costs of 560 k€; which was much less than the initial idea of a bridge with costs of 0.9 million € . At the end, the total cost of the construction amounted to 410 k€, a cost saving of 54% compared to the original plans.

In addition to the economic benefits, the technical solution with mechanically stabilised earth proved itself an easy, safe and trouble-free method of construction.

Figure 8. Chronology of the project in Rodlau

The second presented project deals with an avalanche protection bund in the Tyrolean Alps, using geosynthetic-reinforced earth. From its size it will become the biggest protection measure in Austria. Again the benefits of construction technique and construction cost turned the balance to a geosynthetic solution. The works on the bund started in the summer of 2007 and will be finished in 2010.

Figure 9. Site view of the protection bund Diasbachalpe

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