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GEOSYNTHETIC REINFORCED PROTECTION STRUCTURES IN MOUNTAINOUS REGIONS EXAMPLES OF SAFE AND COST-EFFECTIVE ALTERNATIVES TO CONVENTIONAL STRUCTURES

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ZUSAMMENFASSUNG

Für Schutzbauwerke gegen Felsstürze und Lawinen sind Aspekte der Sicherheit, Baukosten und Materialverfügbarkeit genauso von entscheidender Bedeutung wie die nur begrenzt zur Verfügung stehende Bauzeit. Durch die Verwendung von Geokunststoffen werden wirtschaftlich und technisch einwandfreie Lösungen erzielt.

Nach einem schweren Felssturz im Tiroler Inntal waren umfangreiche Sofortmaßnahmen zur Sicherung der betroffenen Anrainer erforderlich. Die Lösung bestand in der Errichtung von 2 Schutz- und Rückhaltedämmen. Um Schüttmaterial einzusparen und gleichzeitig bessere Rückhalteigenschaften zu erzielen, war die Bergseite der Dammbauwerke übersteilt. Für die Bewehrung beider Schüttkörper wurden hochzugfeste Geokunststoffe verwendet.

Die Talseite einer Lawinen-Ablenkmauer wurde als begrünte Geokunststoff-bewehrte Konstruktion ausgeführt. Dadurch konnte das optische Erscheinungsbild des Bauwerkes erheblich verbessert werden und der erforderliche Bedarf an Platz und Schüttmaterial wurde wesentlich verringert. Unterschiedliche Erosions-Schutzmaterialien wurden erprobt und das Langzeitverhalten der Vegetation wurde untersucht.

Key Words: Schutzbauten, Geokunststoffe, Bodenbewehrung, Erosionsschutz

ABSTRACT

For bunds giving protection against falling rocks and avalanches, aspects of safety, construction cost and availability of materials are of decisive importance as well as the limited time available for construction. The use of adequate geosynthetics leads to an economically and technically optimum solution for such protection walls.

After a severe rock fall in the valley of the Inn in Tyrol, exhaustive measures for the safety of the inhabitants were necessary. The solution for the safety of the village lying below the fall was found to be the erection of restraining bunds to retain the falling rocks. In the intervening period it was necessary to evacuate 285 people from the endangered zone. The steeper slope led to a considerable reduction in the fill material required and thus to a shorter construction time. For the reinforcement of the slope, high-strength geo-composites were used.

A vegetated geosynthetics-reinforced structure formed the lower part of an avalanche-protection bund, enabling the optical appearance to be improved. The area available for the construction was very limited and a considerable reduction in required fill was achieved. Different erosion-protection fabrics were tested and the long-term effects on vegetation growth were studied.

Key Words: Protection Structures, Geosynthetics, Soil reinforcement, Erosion protection

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PROTECTIVE STRUCTURES AGAINST FALLING ROCKS AND AVALANCHES

For both types of structures, be it against falling rocks or avalanches, biological measures (vegetation) are indispensable. However, when large volumes of rocks or snow 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 protective 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 geotextiles, very often using on-site fill material. High-strength geotextiles allow the construction of steeper but still stable slopes. Furthermore, optically attractive solutions can be provided due to different configurations of the surface of such slopes.

PROTECTION DIKE AGAINST FALLING ROCKS ON THE EIBLSCHROFEN



On July 10 1999, rocks the size of houses came loose on the Eiblschrofen hill near Schwaz / Tyrol and plummeted down to a small village.

After these dramatic events immediate measures had to be taken. 110 families – a total of 285 people – had to be evacuated from the endangered village. In order to protect the houses from further falling rocks, extensive protective measures had to take place.

Fig. 1 Construction of the geotextile reinforced embankment at the toe of the mountain; Photo: M Scheibner ILF
Abb. 1 Bau des Geokunststoff-bewehrten Dammes; Foto: M. Scheibner

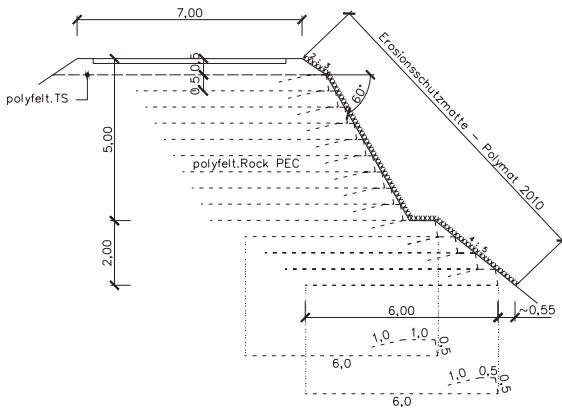
Two retaining dikes were constructed uphill of the village. The larger one has a height of 25 m and a base width of 80 m. In total, the volume of both dikes is 180.000 m³. The dikes had to be designed and constructed in the shortest possible time. The maximum allowable construction time was 3 months, and this target was beaten [1].

A specific problem was the danger of further falling rocks during construction which made work extremely dangerous for the construction personnel.

The uphill slope was made as steep as possible in order to retain further falling rocks efficiently, and to save fill material. For this steep slope, high-strength geosynthetics proved to be the optimum solution.

The site was owned jointly by the Municipality of Schwaz and the "Wildbach und Lawinerverbauung" (WLV), Tyrol. Design was done by WLV, Univ. Prof. Brandl, Consulting Engineers ILF, Innsbruck and Dr. Hammer, and construction work was carried out by a joint venture between the contractors Koppensteiner, Stuaq, Fröschl, Alpine.

Designer and experts agreed that a cost and material-saving method had to be adopted. By using geotextile reinforcement it was possible to construct a steeper slope, thus saving a large amount of fill material. Furthermore, the cohesion of the dike was increased by the geotextile



layers, improving the resistance against dynamic forces caused by possible rock avalanches. [2] Additionally, the geotextile variant allowed a steeper slope on the uphill side, increasing the available collecting space.

Fig. 2 Cross section of the embankment
Abb. 2 Querschnitt der Dammkrone

The dike was constructed with slopes of 2:3 (downhill) and 4:5 (uphill). On top of this dike, a 5 m high geotextile reinforced earth wall was erected. The crest width of the dike is 7 m. In order to allow better vegetating, a slope angle of 60° was decided on. The wedges between the reinforcement layers were filled with topsoil and covered with a monofilament erosion-protection mat.

The slope stability was ensured by several layers of polyfelt.Rock PEC 200 high-strength composite geotextile. This product is a mechanically bonded continuous filament nonwoven reinforced by high-strength polyester yarns. The product was chosen because it provides the following benefits compared to other products:

- High stiffness modulus (high tensile strength at low elongation).
- Excellent water flow capacity in its plane to ensure quick dissipation of excess pore-water pressure. [3]
- High resistance against installation damage due to the non-woven protecting the reinforcing yarns.

The internal stability was calculated using limit-equilibrium analysis. With regard to the geotextile, two cases had to be investigated:

- Pullout of the reinforcing layer (calculation of the anchor length)

- Break of the reinforcement layer (calculation of the ultimate tensile strength)

What almost all design methods have in common is the use of a partial safety concept using specific reduction factors for the ultimate tensile strength. These product-specific factors must take into account creep, installation damage and environmental factors (such as chemical attack).

Considering all these design criteria, a reinforcing composite geotextile was selected. Steel-mesh formwork, bent to the required angle, was used to construct the face. The vertical reinforcement spacing was 50 cm, the anchor length of each reinforcement layer 6 m.

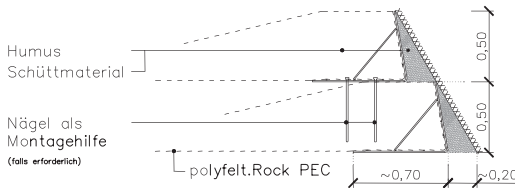


Fig. 3 Detail of the slope surface
Abb. 3 Detail der Böschungsvorderkante

Construction of the dikes commenced at the beginning of August, and was finished after an extremely short period of just two months. This represents very efficient work, with an average of 100 m³ per hour, for a total fill quantity of 180.000 m³! The use of the geotextiles had no negative effect on the speed of construction. By mid- October, the two mighty dikes were finished.

AVALANCHE-PROTECTION WALL IN LANERSBACH



Fig. 4 Avalanche-protection wall Lanersbach, downhill view
Abb. 4 Lawinenschutzmauer Lanersbach, Ansicht talseitig

The appearance of the downhill face of an avalanche-deflection wall made from concrete was made more attractive with a geotextile-reinforced earth structure. The small area available was able to be used effectively, and a considerable saving in fill material was achieved. During the design of the wall in Lanersbach (Tyrol) it was decided to integrate the structure into the surrounding landscape. Lanersbach lies in the Zillertal, at an elevation of 1.350 m, in one of Austria's largest landscape-protection areas.

The local Forest Authorities insisted on covering the wall with a vegetated structure. The geosynthetic-reinforced earth structure was built directly adjacent to the concrete wall, offering the following decisive benefits:

- The structure could be constructed separately from the concrete wall
- The vegetated earth wall could be built to 75% of the height as the concrete wall
- The slope angle of 60° resulted in a minimum required space

- o Vegetating could be carried out with locally available plants and bushes
- o The edges of the structures could be completed with a block revetment.

In the design phase, different possible vegetation methods were investigated, and a slope-stability analysis was carried out. This was done with the help of the computer program "reslope", resulting in the use of the high-strength composite geotextile polyfelt.Rock PEC, with an ultimate tensile strength of 50 kN/m. This computer program allows the use of slip circle analysis and partial reduction factors.

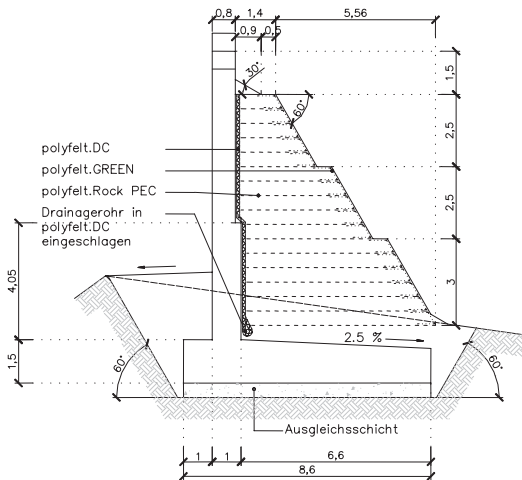


Fig. 5 Avalanche-protection wall Lanersbach, cross section

Abb. 5 Lawinenschutzmauer Lanersbach, Querschnitt

- o The main reinforcing element was installed horizontally in order to transfer the tensile forces into the back part of the structure. Based on the soil parameters (friction angle $\phi = 30^\circ$, unit weight $\gamma = 20 \text{ kN/m}^3$), a vertical spacing of 50 cm and an anchor length of 5.5 m was chosen at the toe.
- o Furthermore, a vegetation geosynthetic was installed into the formwork in order to protect the newly erected earth wall from surface erosion by rain and wind.

In this project, four different, newly developed vegetation geosynthetics were used, in order to investigate their effect on the development of the vegetation. Each geosynthetic was installed over a surface area of 50 m². The products used were:

- o Polymat, a monofilament mat
- o Envirofelt, a 7 mm hick nonwoven with perforations to allow plant growth
- o FC 025, a composite made from cotton and HDPE
- o Glass grid with an aperture size of 5 mm

The avalanche protection wall had a height of up to 10 m, and was constructed on a 1.5 m high strip foundation. In order to facilitate maintenance of the slope, 3 berms with 50 cm width were integrated.

Drainage takes place both in the plane of the composite geotextile, and via a drainage composite and drainage pipes installed underneath the retaining structure. Vegetation was first applied in June 2000, directly after completion of the works, and a second time in September.

The investigation of the vegetated surface in August 2001 showed that greening had been very successful. The vegetation was so dense that the underlying structure was no longer visible. The sacrificial formwork (steel mesh) and the vegetation geosynthetics had interlocked perfectly with the plant roots. It was not possible to excavate the steel mesh by hand, as the grass was more than 50 cm long. The slope had a very natural appearance. No distinction could be made between the four sections with the four different vegetation geosynthetics used.

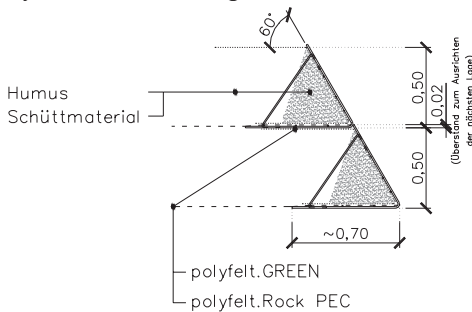


Fig. 6 Avalanche protection wall Lanersbach, Detail
Abb. 6 Lawinenschutzwand Lanersbach, Detail

CONCLUSIONS

In the alpine regions specific boundary conditions of construction design and execution have to be taken into account. Especially for bunds giving protection against falling rocks and avalanches, aspects of safety, construction cost and availability of materials are of decisive importance as well as the limited time available for construction.

It could be shown how the use of adequate geosynthetics leads to an economically and technically optimum solution for such protection walls.

Due to these reasons the use of geosynthetics in this application has a high potential for growth in the future.

LITERATURE

- [1] Bayer H., Gsell A., Hammer H., Sauermoser S. und Scheiber M., Planning of Mitigation Measures regarding the Aggravated Risk imposed by Rockfall, Felsbau Nr. 18 / 2000
- [2] Brandl, H., Adam, D. 2000, Special Applications of geosynthetics in geotechnical engineering 2nd European conference on geosynthetics, Bologna 2000
- [3] Oberreiter K., Mannsbart G., Loke K.-H. , Delmas Ph., Überlagerung von Drainage- und Bewehrungsfunktion von Geotextilien in feinkörnigen Böden; 8. K-Geo, TU-München 2003