Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical Engineering

doi:10.3233/978-1-61499-656-9-2507

Landslide rehabilitation with geosynthetics in the open coal mine Oslomej-West

Réhabilitation du Glissement de Terrain à l'aide de géosynthetics dans la Mine ouverte de charbon Oslomej

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ABSTRACT

In November 2002 soil stability was violated and landslides were registered in the open coal mine Oslomej-West, Republic of Macedonia. Around the profile IV, the existing open irrigation canal was cut off and landslide extended to the regional road R421 Kichevo-Oslomej. The landslide was classified as being big and hazardous, including the danger of discontinuing the regional road as well as the pipeline Studenchica-Oslomej for utility water supply to the thermal power plant Oslomej.

In accordance with the proposed solution, the final design for landslide rehabilitation was prepared implying use of geosynthetics Stabilenka 200/45. When the high tensile strength Stabilenka was installed in soil (local alluvium - diluvium material) which was being placed and compacted in layers, it formed a composite material consisted of geosynthetics and soil. Stabilenka acts as reinforcement due to its high frictional properties and its ability to absorb tensile forces. In accordance with the design solution, two retaining walls of reinforced soil have been constructed on soft subsoil (clay) where the risk of bearing capacity failure was imminent. By installing Stabilenka between the foundation clay and local alluvium - diluvium material used as backfill for the retaining walls, bearing capacity of the soil was greatly increased.

Also designed was a complete drainage system with geocomposite materials in order to reduce saturation of clay subsoil and ground water level. In this case geocomposite materials had filtration and drainage function. The design has been performed in accordance with the limit equilibrium theory and the finite element method.

This paper deals with some details of the design and execution of the landslide rehabilitation.

RÉSUMÉ

Au mois de novembre 2002 on a remarqué qu'il existe une violation de la stbilité de la mine ouverte de charbon Oslomej, R. de Macédoine et un glissement du sol.Autour du rofil IV le canal ouvert d'irrigation existant a été interompu et le glissement du sol s'est élargi tout au long de la route régionale R 421 Kicevo-Oslomej.Le glissement du sol est classifié grand et dangereux qui peut résulter avec une rupture de la route régional et du pipe-line Studencica – Oslomej qui fournie des eaux techniques à la centrale thermique.

D'après la solution proposée on a élaboré le projet général de la sanation de glissement du sol à l'aide de géosynthetics Stabilenka 200/45.Après avoir instalé dans le sol une Stabilenka d'une haute puissance de traction (materiel local alluvion – dilluvion) étant placée et compactée en couches, elle a formé un composite du géosinthétique et du sol.Stabilenka agit comme un renforcement dû à ses hautes caractéristiques de friction et à son habilité d'absorber les forces de traction.D'après la solution du projet, on a construit deux murs de soutènement en sol renforcè sur un sous-sol doux – en argile où le risque de défaut de la capacité portante est rapide.En instalant Stabilenka entre l'argile de fondation et le matériel local alluvion – dilluvion étant une sorte de ramblayage des murs de soutènement, la capacité portante du sol a été fortement augmentée.

De même, on a projeté un système complet d'évacuation dan le but de réduire la saturation du sous-sol en argile et de diminuer le niveau des eaux souterraines.Dans ce cas, le matériaux géocomposites ont la fonction d'un filtre et de l'écoulement.Le projet est réalisé en conformité avec la théorie d'équilibre des limites et la méthode des éléments finis.

Cette oeuvre traite en détail la projections et la construction de la réhabilitations du glissement du sol.

1 INTRODUCTION

In accordance with the worked out and proposed conceptual design for rehabilitation of the landslide face on the stretch profiles III and V, dated December 2002, as well as the disrupted stability and originated subsequent land sliding on the above analysed stretch, a need has been imposed for a complete rehabilitation on this part of the open coal mine Oslomej-West with a view of facilitating its further safe operation.

2 TECHNICAL SOLUTION

As part of the proposed conceptual design, the actual condition of profile IV has also been analysed, in accordance with the situation as it was surveyed and recorded on the 8 November 2002 and it was also simulated a subsequent land sliding up to the drainage channel, owing to the unsatisfying coefficient of safety.

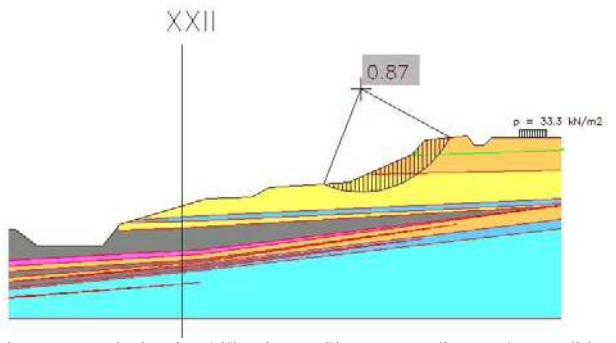

Figure 1. Analysis of stability for profile IV according to the condition on the 8 November 2002

Owing to non-undertaking working activities for rehabilitation, registered have also been subsequent landslidings, especially around the profile IV, so that in that part the channel has been discontinued and the landslide expanded to the regional road R421 Kichevo - Oslomej-West. On the account of that evolved situation, endangered has been the safety in using the regional road, as well as the existing pipeline Studenchica - Oslomej which enables supply of utility water to the thermal power plant. The condition prior to commencement of rehabilitation is presented in Figure 2:

Figure 2. Land sliding about profile IV - condition on the 11 February 2003

In parallel with the preparation of the final design for rehabilitation of the landslide between profiles III and IV, commenced has also been the execution on the most critical part, as interventionist rehabilitation measures. The time variant of the final design and stability analysis has been carried out on the basis of detailed geodetic surveying dated 2 April 2003. On Figure 3 is presented the designed site plan of the rehabilitated stretch along with the retaining walls comprising geosynthetics and the entire drainage system for surface-water tapping and lowering the ground water level. Number 1 designates the open drainage channels which are directed towards the water collecting sumps in the open coal mine and which take on waters that have been intercepted by drainage prisms - number 2, whose objective is reduction of state of ground drainness (in this particular case saturated clay). Drainage prisms have been worked out of quartz raw material, wrapped with geotextile from underside and Enkadrain from the upper side, the terminations of which are at the lateral side of the open channel. Number 3 designates the closed drainage channel that stretches out longwise the length of the entire rehabilitated stretch behind the retaining walls of system reinforced earth, which is designated with number 4. This drainage channel enables cutting off the front line of supplementary feeding of the open coal mine with sub-soil waters as well as their capture, thus also protecting the infill of the retaining walls against excessive wetting. At the above mentioned site plan also presented are the analysed profiles on the basis of which design has been performed for rehabilitation of the landslide.

The retaining walls (of system reinforced earth) have been designed and constructed with geosynthetic materials as well as deluvial material as infill, by means of which it has been made possible to rehabilitate the face of the landslide and extension of the stripped part along the road.

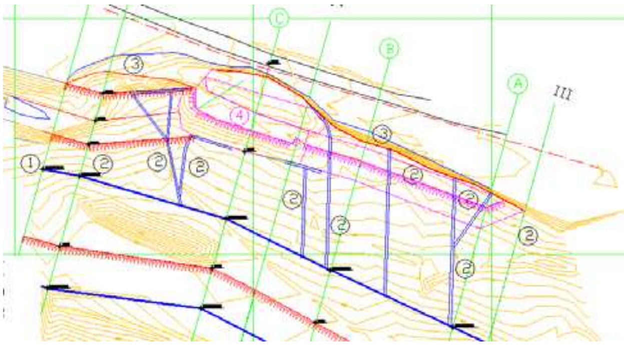

Figure 3. Design site plan of the rehabilitated stretch

2.1 *Characteristics of geosynthetics*

Geosynthetics, being polymer materials, flexible regarding large deformations and large tensile forces, are deemed to be most suitable for rehabilitation of landslides having distinctly deformable soil, in the first place due to the fact that it is a matter of flexible structures possessing high degree of interaction with soil layers, as well as owing to the acceptance of shearing stresses. In continuation cited are geosynthetic materials used for rehabilitation along with their basic properties and functions.

In designing retaining walls of type reinforced earth, employed have been geogrids (in this particular case Fortrac 35/20-20 and Stabilenka 200/45) as well as local material diluvium as infill between layers. The first designation of geogrids denotes the ultimate force in longitudinal direction, while the second one denotes the ultimate force in transverse direction. In designing, the ultimate force which the geogrid possesses, is being reduced by means of reduction factors (installation during execution, biological and chemical degradation and also creeping and yielding of the material) so that one can calculate the allowable tensile strength of the geogrid. In designing the fill with reinforced earth, we also dimension the geogrid type, its length and anchorage length.

The anticipated Fortrac geogrids have been engineered using polyester fibres jointed in bundles or bunches and also using polyamide cover. According to the ultimate tensile strength, they are classified into a number of types. The basic properties of Fortrac geogrids are as it follows:

- high tensile modulus;
- minimal deformations at creep and yielding and long-term hold of tensile force;
- resistance to chemical and biological degradation;
- simple and fast execution of works;
- high interaction with the soil material which is used as infill.

At the face of the retaining wall, where Fortrac geogrids have been anticipated to be used, it is necessary to place geotextile which wraps the face of the retaining wall, this ensuring hold of the infilling material and, in case of placing top soil with seed for grassing, accelerated grassing is made possible.

Stabilenka is a high strength and high quality woven geosynthetic, made of polyester bundles in longitudinal direction and polyamide or polyester bundles in transverse direction. Strains at creep i.e. yielding are limited to 1% after two years of service. Taking into consideration the considerable tensile forces it possesses, this material is employed for reinforcing the soil at retaining structures when stabilizing the slopes. With regard to the fact that Stabilenka is of woven structure, this material possesses both reinforcing and separating function and so for that reason it is not necessary to use geotextile. In this particular case, the analysis has confirmed that Stabilenka 200/45 is a satisfactory type of material, taking account of the reduction factors in establishing the allowable tensile strength.

Enkadrain is a composite which consists of a drainage layer placed into sandwich between two geotextiles. Drainage layer is composed of tough and wrapped polyamide fibres, which are jointed in the sections and at the same time they form openings with a coefficient of openings 95%. The geotextile layer is made of polyester nowoven textile of a thickness 0,7 mm. The three layers are mutually thermally interconnected.

The main functions of Enkadrain are:

- Filtration
- Drainage
- Protection.

- *Properties of Enkadrain*

The main properties distinguishing Enkadrain are the following:

- High ability for percolation and discharge;
- Safeguarding the protective layer against damages;
- Formation of insulating air layer between the wall and the soil;
- Protection of the header pipe against blocking with silt;
- Easy for installation under any weather conditions;
- It does not decay or decompose, so that there is no risk of soil contamination
- It does not react to chemicals, which are usually encountered in the soil;
- It is of light weight, easy for cutting, leaves insignificant waste during installation and provides protection against penetration of roots.

Geomembranes, being geosynthetic materials, are manufactured of polyethylene of high density (HDPE), high flexibility and of certain flexible polypropylene. The manufacture of geomembranes is achieved in three ways: by means of extrusion i.e. squeezing and impressing, by fabric producing machines and by coating with a protective coat. The primary function of geomembranes is their impermeability. As an observation we would mention that there is no material possessing absolute water impermeability, so that in the case of geomembranes this coefficient of water permeability amounts to about $1x10^{-9}$ m/s. Geomembranes are used for ecological, geotechnical and hydraulic working activities i.e. applications, where it is necessary to ensure water impermeability.

2.2 *Drainage system*

With regard to the complex hydro geological condition of the ground, for a successful rehabilitation it is necessary to provide proper drainage and lowering the ground water level, which is of enormous significance and influence, so that in conducting the stability analysis special attention has been paid to devising a comprehensive drainage system composed of open drainage channels 1.5 m deep, as well as drainage channels min 0.5 m deep at each level dig. At the same time, the first layer of the design retaining walls of reinforced earth is necessary to be carried out of drainage material (quartz raw material), while at certain distances drainage prisms have also been designed heading under the retaining wall constructed of reinforced earth up to the first main drainage channel. For cutting off the front line of supplementary feeding the ground waters into diluvium stratum, immediately behind the slope it has been anticipated a drainage channel of variable depth, filled with quartz raw material and Enkadrain at the side of the drained slope and geomembrane at the opposite side. In this case the ground water infiltrates through the filter layer of Enkadrain and then through a polyamide core it descends to the bottom of the drainage channel and thanks to the longitudinal grade it directs outside the slipped zone being rehabilitated. The water impermeable geomembrane prevents infiltration of the captured ground water in the filled material, infill of the retaining wall, while for the capture of the surface water in the toe of each level dig it has been anticipated an open channel of longitudinal grade.Figure 4 presents the designed and constructed drainage prism.

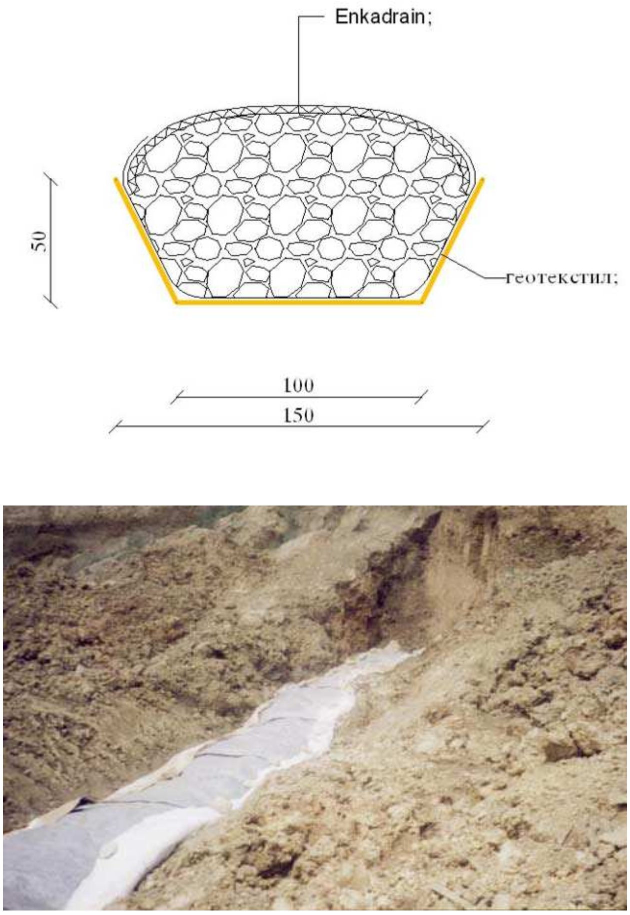

Figure 4. Designed and constructed drainage prism

2.3 *Construction*

For establishing also an addition to the existing level-digs within the open coal mine Oslomej-West, designed have been two retaining walls of a system reinforced earth, of different length of stretching, different height and differently reinforced, depending on the tensile forces that geogrids should take on and all in compliance with the stability condition, where geogrids have been simulated and their positioning within the analysed profiles A-A, B-B, C-C and D-D. At the same time, the retaining walls of system reinforced earth have been precisely positioned in the designed condition.

The upper retaining wall has been constructed by placing one layer of Comtrac 35 having separating, filtering and reinforcing function as well as a layer of local material 0.5 m high. The layer of Comtrac has been anchored with a minimum anchorage length of 2 m. In accordance with the design, the first layer should be made of drainage material, thus preventing the increased condition of drainness of the retaining wall system reinforced earth.

Figure 5. Construction of the first layer of Comtrac on the upper retaining wall of system reinforced earth

On top of the first layer, designed have been three layers of Fortrac 35/20-20 of 0.5 m thickness of each layer, where local diluvium has been used as infilling material. In the background of the retaining wall, commenced has been execution of a drainage channel by letting a sufficient length of Enkadrain along the slope, which will be a constituent part of the drainage channel after ascending the retaining wall.

By means of simulation according to the finite element method and using the Plaxis software for geotechnical design, it has been determined the impossibility for complete ascending of the upper retaining wall along the anticipated stretch (in accordance with the design), without commencing the construction of the second retaining wall and without filling tailings material in the toe of the landslide. The simulated state of failure for this presumed way of rehabilitation (without the second retaining wall) is presented in Figure 6.

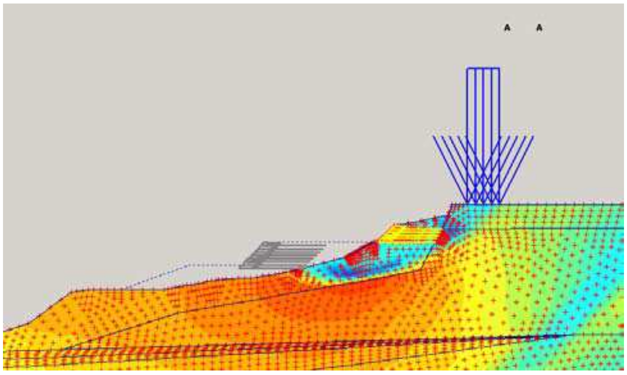

Figure 6. Simulated state of failure for the execution of the first retaining wall only

The upper retaining wall is 3.2 m high comprising one layer Comtrac 35, three layers of Fortrac 35/20-20 and two layers of Stabilenka 200/45 of 10 m length. The height of the last two layers is 0.9 m each, while that of the remaining ones is 0.5 m. The anchorage length is 2 m for each layer of the retaining wall. This retaining wall has been anticipated for the stretch 68 m long, where land sliding approaches the road and endangers its function.

The second retaining wall is of special significance for the rehabilitation of the landslide from a viewpoint of stability, taking also into consideration the surrounding infrastructure. It has been so designed as to be of height of 5.4 m, that is to say six layers of Stabilenka 200/45, so that the thickness of each layer of infill is 0.9 m. The first layer should be strictly drainage material and subsoil drains in the form of drainage prisms at certain stretches, where wetting of the no rehabilitated slope is obvious. The first layer of Stabilenka 200/45 is 10 m long, while the remaining five layers are each 9 m long.

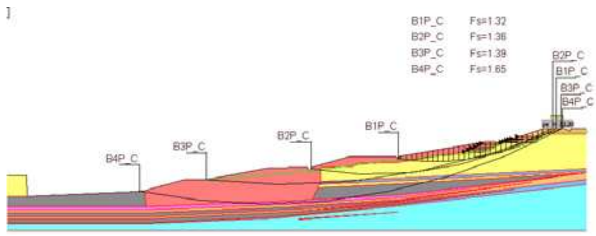

Figure 7. Analysis of stability for profile B-B

The anchorage length by means of which it is provided transfer of the tensile force from the geogrid into the soil amounts to 2 m. It has been anticipated for this retaining wall to extend 211 m in length and so to be a continuation i.e. extension to the existing level dig i.e. bench of quarter, which goes on from profile V. Forming the remaining level-digs i.e. benches and providing stability on the stretch between III and IV profile has been realized with filled tailings material up to the coal toe.

3 CONCLUSION

By means of a complete rehabilitation of the landslide in the open coal mine Oslomej-West, it has been made possible to achieve safe use of the regional road, as well as unobstructed working activity of the open coal mine in accordance with the mining and technological conception. The complex geotechnical and hydro geological condition of the open coal mine imposes permanent monitoring and analysis of the local and global stability in this zone of the open coal mine.

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