Geosynthetic as filter layer for gabions support construction

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ABSTRACT: The road which is the main connection between the southern Croatia and the rest of the country runs parallel with the Adriatic sea coast. The road has been built more than thirty years ago. The road alignment is mostly in cuts because of specific geological characteristic of coastal region. Geological structure of soil and trend of increasing traffic the road has not been designed to, have caused remarkable damage of some its section. Gabion retaining walls have been used for the reconstruction of this road section because of present requirements for environment protection as well as because of good technical characteristics of gabions. The quarry stone that is possible to get from local sources in rather sufficient quantity is used as a filling material for gabions. This type of wall is completely water-permeable and looks like a part of natural environment. Dalmatia is a region with sudden and vast rainfalls. In those situations large amounts of water infiltrate the backside of the wall because of the steep and large areas the rain falls on. There is a problem of protecting of gabion wall against obstruction because of infiltration of small soil particles from the surface and the ground behind the wall into the drainage system of gabion. Calcernites karstfied rocks from the Makarska region are overlain by weakly cemented to well-cemented Quaternary breccia. Weakly cemented breccia has high plasticity red clay as binding agent. That type of material is easily washed out from the soil surface on steep sides of mountains because it is almost without any vegetation and therefore subjected to intensive erosion. This paper presents the use of geotextile as an ideal material placed between large stones of the gabion and the backfill as a protection against colmation.

1 INTRODUCTION

Main Adriatic road which mainly follows Adriatic coast and major part of it's section pass just nearby steep coast, so that is the reason why the road alignment is mostly in cuts. Geological structure of soil and trend of increasing traffic for which it hasn't been predicted (e.g. military transports during the war in Croatia and in Bosnia) have caused the great damage in some parts of the road. During reconstruction of the section of Adriatic road situated south of Živogošće (i mmediately after Hotel "Nimfa" between chainage km 675+770,50 and chainage km 675+950,62) the landslide occurred in the length of 180 m´. During the reconstruction of the road great amount of material from the landslide sled down on the construction site in the length of approx. 100 m´ near the end of the aforementioned section. At the same time, material at the beginning of the section stayed at the root of the slope in a moved and disturbed state. Because this road is the only connection between Dubrovnik and the rest of the country, an immediate intervention was necessary in order to remediate the damage and to ensure the undisturbed traffic. After the landslide occurred, an inspection has been done and actions to solve the problem taken.

The location of this potential landslide has been known for some time. In order to take actions on the site it was necessary to overview and assess the existing investigation works, and prepare survey and geotechnical maps.

Investigation works at this location were took place in 1967 and 1982. A total of 14 boreholes were drilled in the road structure. The boreholes have been used in order to determine the reason for permanent damage of the pavement. Based on the aforesaid investigation works, the solution for the remediation of the road structure has been proposed. The solution consisted of the following actions: replacement of the fill in the height of 2.00 m with the carefully selected material placed as new fill. It was also necessary to repair the drainage which was partly a cause for permanent damaging of the fill. During investigation works it was also observed that autochthonous soil in cut the does not have favorable properties and it should be replaced in thickness of about 2.00 m. During road reconstruction works, stability of the nature slope on the north side of the road was not taken into account. There weren't any investigation works or survey maps of that part of the location, and that was the place where it was predicted to increase the height of the fill for another two meters, in spite of it was very unstable slope. The slope was cut for two meters in the length of 180 m and the material replaced. But new material for the fill was not brought to the place in the moment when cutting of material has finished. Situation was critical for the slope itself, so the landslide moved down towards the road.

Investigation works carried out until that moment were just the base for the program of additional investigations which are necessary for improvement of the landslide which has occurred during road reconstruction. Geotechnical maps were made based on geophysical methods because of inaccessible terrain.

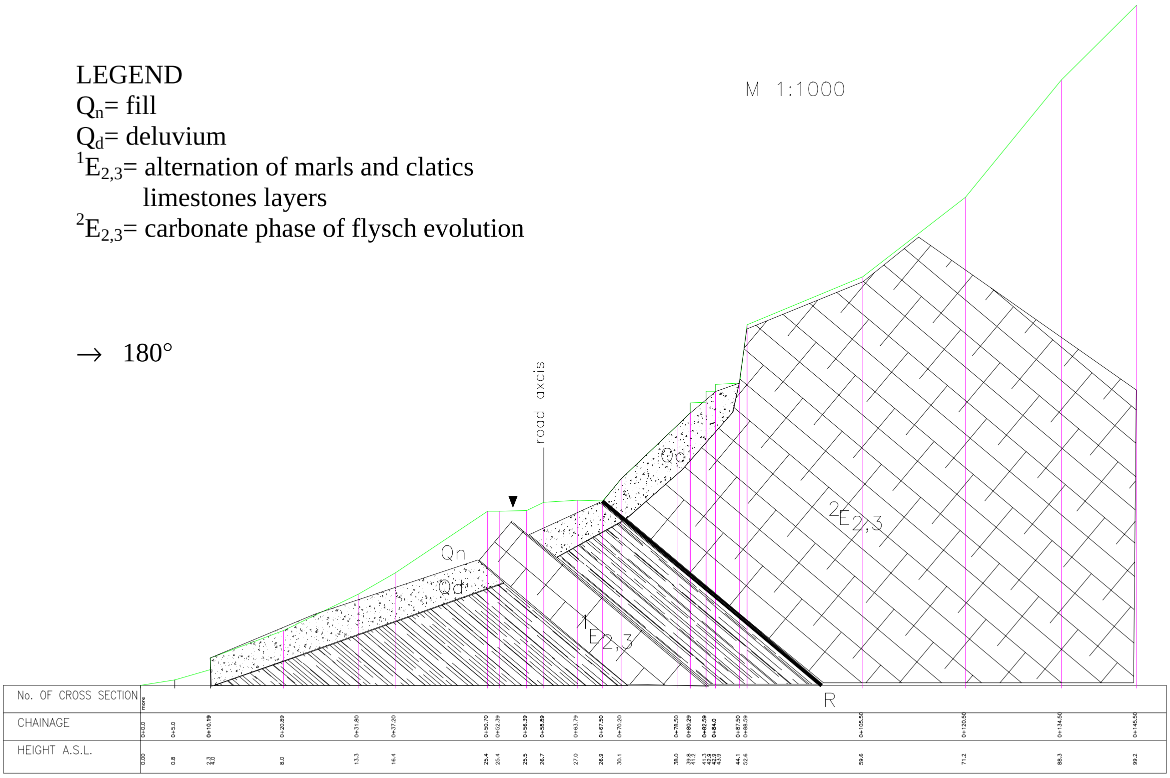

Figure 1. Geological cross-section at the location of the landslide

2 GEOLOGICAL CHARACTERISTICS OF LOCATION

Investigated slope is a part of Biokov's massif built mostly of massive Upper Jurasic limestones (J_3) under which the Eocene flysch ($E_{2,3}$) submerged in a narrow coastal belt. Submerging of flysch is the consequence of collision between the Adriatic microplate and the Dinarides, with the direction of Adriatic microplate movement from south-west towards the north-east. Those sediments are in spots overlain by uncemented to well-cemented deluvial breccia (Q_d).

Geotechnical model was formed based on prognosticated geological profile of the slope. For the modeling it was positive that flysch layers were perpendicular to the slope surface. Since, beside marls, occurrence of approx. 10 m thick layers of clastics limestones has been registered in flysch from 45 m a.s.l. to 55 m a.s.l., analysis has been conducted for uncemented breccia which occurs in the slope below 45 m a.s.l. Upper part of the slope, built of clastics limestones, is partly overlain by deluvial breccia which is unstable in some its parts and is dangerous for the traffic security. Geological cross-section is shown in Fig. 1.

From the geotechnical point of view it should be mentioned that the surface of the analyzed slope consists of weakly cemented to uncemented Quaternary breccia with the occurence of some limestone blocks (some of them with the volume exceeding one cubic meter).

According to the existing geotechnical investigations in 1967 and 1982 as well as detail geological works connected directly with the problem of landslide, it has been established that the road section of interest has been built in thick strata of marly components of flysch series. Marls are partly overlain by deluvial uncemented to weakly cemented breccia and partly by the road fill.

Geometry of the cut after sliding was used for parametric analysis of shear strength of Quaternary breccia occuring in the slope surface.

3 ANALYSIS OF STABILITY

For the analysis of landslide stability parametric analysis have been used. The reason was a lack of information on physical-mechanical properties of the material. Soil parameters for deluvial breccia used in calculations are given in Table 1.

Analysis of stability has been conducted by numerical modeling using computer program FLAC (Finite difference method). Prognosticated geological cross-section used for modeling has been completed with soil parameters obtained by the analysis of stabile parts of the slope as well as field reconaissance and field classification of the material. The critical state tested on a model is the moment immediately following the slope cutting for purposes of road fill reconstruction. Limestones have been modeled as homogenous media. General inclination of flysch layers is towards the north-northeast with north-northwest/south-southeast strike direction which makes the slope safe and makes it possible to model the material as homogenous. Obtained safety factors are given in Table 1. The results of the modeling coincide well with the geometry of the landslide following the sliding. The model shows that cutting of the root of the slope caused the sliding.

Table 1. Parameters of soil used in num. model.

Group number	Angle of friction φ [°]	Cohesion c [kPa]	Safety factor Fs	State of num. model
1	45	2	0,84	stabile
2	40	2	1,00	stabile
3	35	1,68	1,19	stabile
4	30	1,37	1,45	stabile
5	25	1,12	1,78	unstable

After that, a model with retaining structure has been calculated. Retaining structure was chosen with the view to change part of the material in cut and to stabilize the slope. Connection between the wall and soil behind it has been done by a layer of well-compacted material. This layer provides a connection between the wall and autochthonous soil immediately after construction.

In that way, already after placement of the first row of gabions, the height of the landslide is decreased and stability of slope increased. For the construction technology it was important to place gabions on the ground from which the fill was removed up the slope. The reason was not to overcome stability of the slope. It was necessary to anticipate the structure which will be able to undergo some deformation without damage, which is insensitive to water impact, not too heavy and can be finished in a short time. A good property of the gabion retaining wall is that from the moment of placement it has it's full bearing capacity. In this case this was important because of the urgency to continue with the road reconstruction.

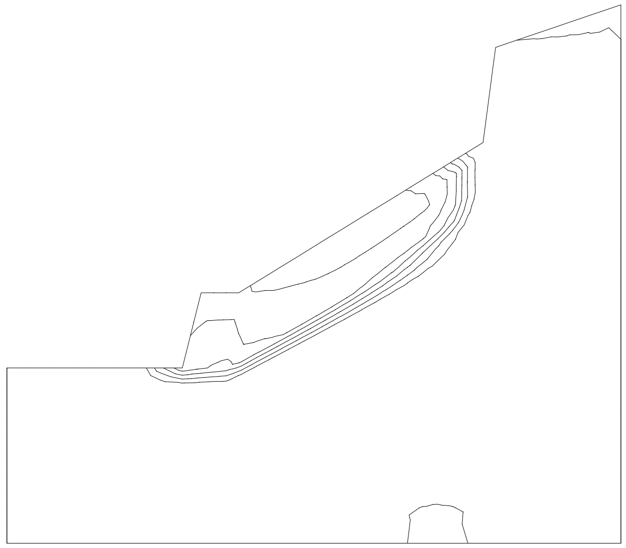

Figure 2. Horizontal displacement on numerical model for reconstruction with gabions.

Because of all those reasons gabion retaining wall has been chosen. The wall inclination angle is 3.33:1 which means that each gabion (1.00 m height) is displaced towards the slope for 0.30 m. In that way, impact of active earth pressure is decreased. Calculation of stability has been performed for the slope with a new retaining structure and shear strength parameters of soil: $\varphi=40°$, c=2 kPa. Safety factor F_S = 1.00 was used in basic analysis in order to determine the aforementioned parameters. The results of the calculations show that critical slip surface is located under the retaining structure. A model with the retaining structure (Figure 2) gave the safety factor F_S=1.7. Besides stability analysis, stresses on the contact between gabions and soil have been calculated as well as the settlement. All the results were favorable.

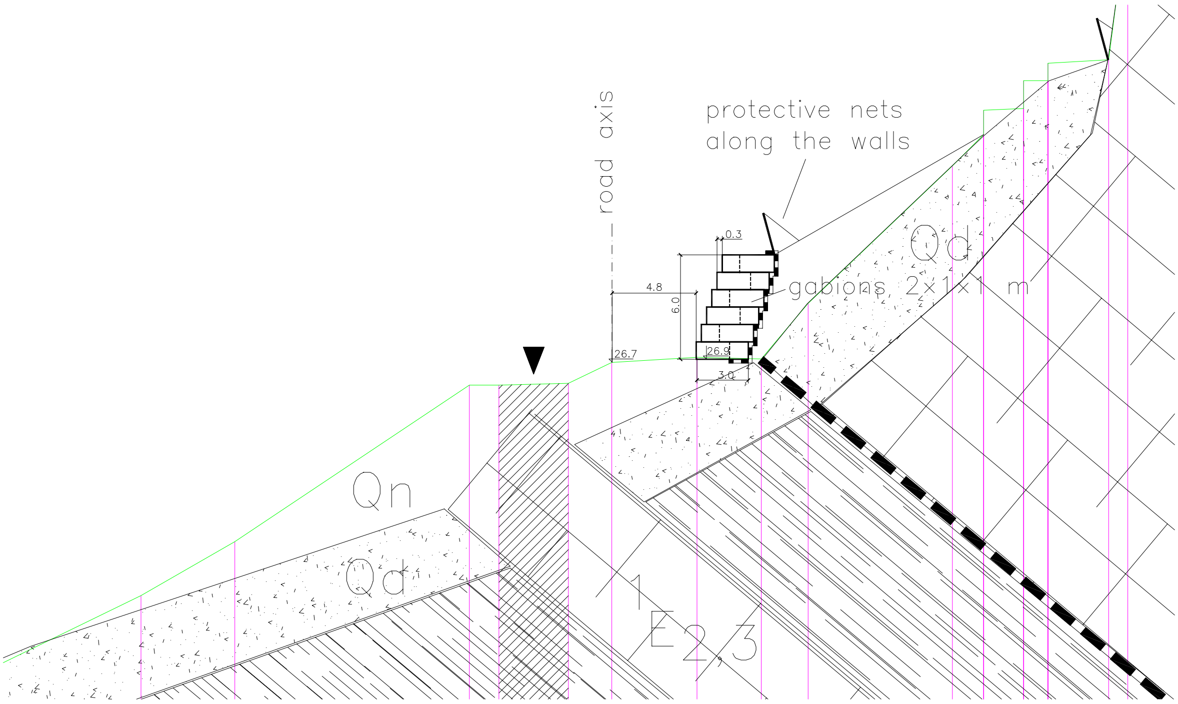

Figure 3. Cross section of reconstruction with gabions and protective nets

4 SUGGESTED MEASURES FOR THE LANDSLIDE IMPROVEMENT

Protective structure should consist of two independent parts. The first part is 6.00 m height gabion retaining wall. The wall is shown in Fig. 2. It consists of six rows of gabions, with dimension 1×1×2 m. Each row is displaced from the face of the previous row by 30 cm.

The second part of the protective structure is an elastic protective net, located on the slope above the cut in the length of 30% off the road section, which should protect the road against falling of small and big rock fragments and rock blocks,.

For an immediate protection of the road against falling of uncemented deluvial breccia, it is foreseen to place the protective net on the top of the wall in its overall as shown in Fig. *3*.

5 DESCRIPTION OF PROTECTING CONSTRUCTION

Based on described model, the slope is improved by construction of the retaining wall. The reason for choosing that kind of retaining wall are: flexible construction, simple and rapid construction. Besides that, it should be taken into account that the retaining wall shall not produce additional load on the potential slip surface, which could cause a collapse of the road fill. A gabion retaining wall was chosen as the best solution.

This type of wall doesn't require special drainage of the back side while collection of infiltrated water shall be solved as a part of road drenage. Gabion wall looks like a simple stone wall and it fits well in the environment. With regard to the layout, the wall follows the edge of the road at the distance of approx. 1.00 m.

Geotextile is placed directly on the soil behind the wire netting of the gabions. Therefore, the gabions are completely separated from the soil by geotextile as shown in Fig. 4. With regard to the layout, gabions were placed in two rows - one parallel with road and the second perpendicular to it.

Gabion in the first row is 2.00 m long while the perpendicular ones together have dimension of 2.00 m. Few gabions placed in the first two (vertical) rows are shown in Figure 4. The first row of gabions will be been placed on the geotextile, after that a backfill in the same height (1.00 m) will been placed behind the gabions; the sequence of placement will than be: the next row of gabions, geotextile, backfill, until the sixth row has been finished.

Specific function of gabion retaining wall is drainage of water. Geotextile stops washing out of the material behind the gabions. At present there is a variety of material that can be placed as backfill and the material found at the location can be also used as backfill. Deluvial breccia is cemented with high plasticity red clay. Because of geotextile, clay can not be washed out and fill the space inside the rocks fill in the gabions. The other advantage is a big reduction in transportation costs which would be much higher if a material from some other location is used. Construction time is also significantly shorter.

Tensile strength of the geotextile used as a filter for gabion retaining wall has been disregarded in calculation. Its only function is filtering of water so there is no need for special filter layers behind the gabions.

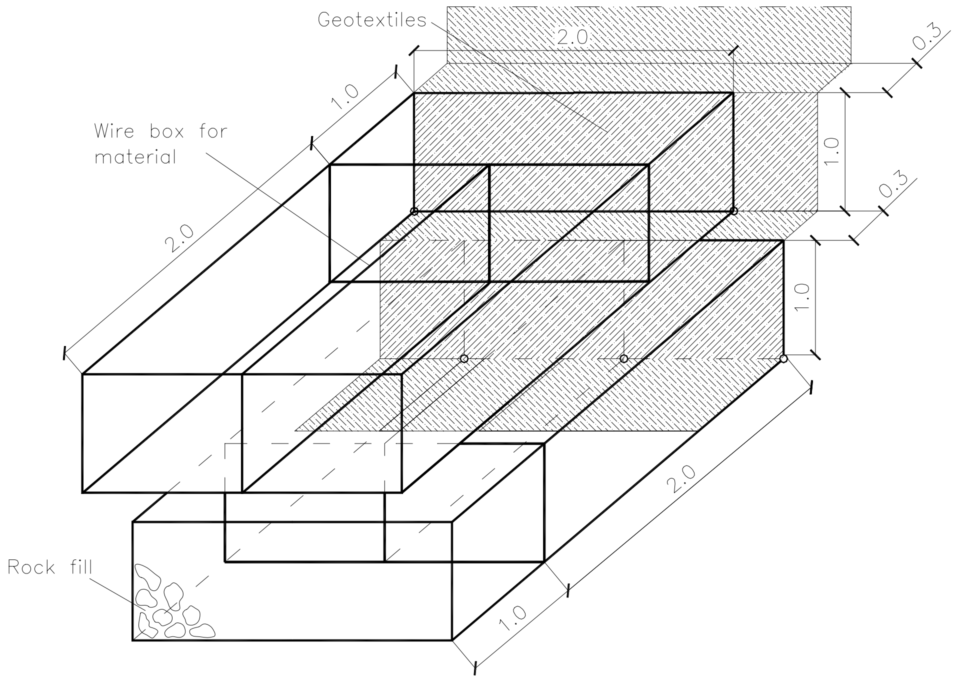

Figure 4. 3D View on gabions

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