Slope stability along a new road "Drisht –Drisht castle"

Stabilité de pente le long de la nouvelle route "Drisht-Drisht castle"

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ABSTRACT: Some slopes along the new road from the village Drisht center to the medieval castle entrance are located in a very disturbed tectonic zone. Due to overthrust geological processes the rock quality are extremely poor. In surface there are different active slides that due to water circulations especially during seismic events are very unstable and slide towards road pavements or cause side channel and culvert fills.
This article describes the numerical calculation concerning frequent normal conditions during construction and use of road and accidental condition during seismic events. Based in these calculations design solution are given. The calculations will be controlled by a back analysis algorithm. We have decided the upper and lower boundaries for the main results and we have made a sensitivity analysis that will show the influence of each parameter to the predicted results. So during maintenance time with same site tests results we can correct numerical parameters used in the model and predict long time behavior of the slope. In this manner we can also correct the future rehabilitation measures (if necessary) for the above mention road slope and other road slopes in similar conditions.

RÉSUMÉ : Certaines pentes le long de la nouvelle route allant du centre du village de Drisht à l'entrée du château médiéval sont situées dans une zone tectonique très perturbée. En raison de différent processus géologiques, la qualité de la roche est extrêmement médiocre. En surface, il existe différents glissements actifs qui, en raison de circulations d'eau lors d'événements sismiques, sont très instables et glissent vers chaussées et remplissent le canal longitudinal.
Cet article présente un calcul numérique (en conditions fréquentes – normales) pendant la construction et l'utilisation de la route. Les conditions accidentelles correspondant à des événements sismiques sont aussi traitées. Sur les bases des calculs effectués, des solutions techniques sont proposées. Les calculs sont contrôlés par un algorithme de "back analysis". Nous avons décidé les limites supérieure et inférieure pour les principaux résultats et nous avons fait une analyse de sensibilité qui montre l'influence de chaque paramètre. Ainsi, pendant le temps d'entretien du site, nous pouvons déterminer les paramètres numériques à utiliser dans le modèle pour prédire le comportement de la pente à long terme. Nous pouvons aussi proposer des mesures de réhabilitation futures (si nécessaire) pour la pente.

KEYWORDS: Slope stability, seismic events, weathering.

1 INTRODUCTION

The new road links the center of the village with a very famous medival castle. It pass through a mauntainous area and need a lot of structures such as retaining walls, culverts, small bridges etc. The last part of the roads pass in a very steep slope where a year after the construction ware seen local slope failures.

Figure 1. Photo of local slope failures

The road width is 6m with 0.5 shoulders and a longitudional concrete paved channel on the side of the mauntain. The road body is partly in filling and partly in cutting. The zone is one of the wetest zone in Albania with a average rainfall of 1750mm/year. Due to lack of budget during the construction phase for finishing all the engineering measures and maintanence problems during exploitation phase local slope slides have occured after a period of 3 years.

1.1 *Geological and geotechnical aspects*

The road to Drisht castle pass through a very disturbed tectonic zone. The study area takes part in subzone Cukali which, in the west and northwest is overthrust from the Albanian Alps zone , and in the southeast area is overthrust from Mirdita zone. Slope of the right side of the road represented by mainly constrained dark color old clays. Inside the clay mass can be meet compact sandstone layers bodies with dimensions up to 1 m in length, and up to 30 cm thickness and sandstone pieces measuring 5 to 10 cm with rounded shape and often alienated. These deposits are turbidits with a clayey - sandy cementation. They are too weak and are divided into small pieces. The above mention formation can be classified as very heterogonous flysch. Within the clay mass at the bottom of the slope (on the right side of the road) can be meet limestones olistolite size 5 to 10 meters above which are placed massive limestone rocks of Triassic geologic time.

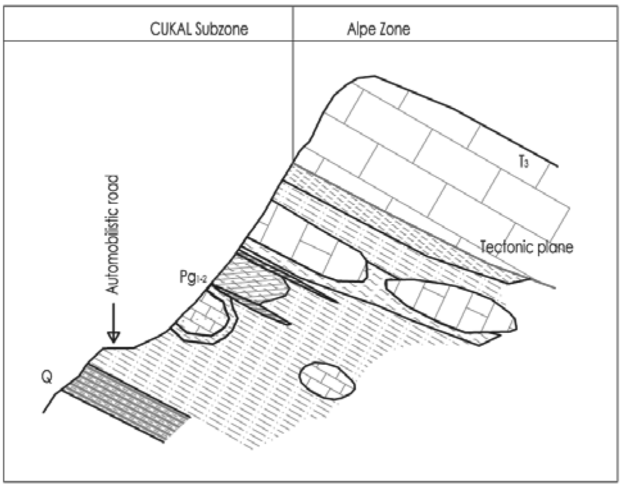

Figure 2. Schematic representation of the geological aspects of the slope

1.1.1 *Geotechnical parameters*

As given above we have identified two main type of terrain. The limestone rock formations with very good mechanical characteristics and flysch formations that are very weak rocks to soils.

These last rocks are described as rocks with relatively low strength and high deformability. They can be easily eroded by water, have a plastic behavior and poor stability on the slopes. Volume weight ranges from 2.2 - 2.6 g/cm^3, porosity up to 35%, elasticity module 2 * 10^3-10^4 daN/cm^2, compression strength 5 - 25 daN/cm^2, intact rock cohesion 20 100 kPa, internal friction angle <15 °.

Based upon the lab test and empirical evaluation the main geotechnical parameters for unweathered formations used in the design are as follows

Table 1. Geotechnical main parameters

Layer	*gs*	*c*	*F*
Flysch/Clay	23	20-100	15
Limestone	26	400	45

2 MODELING OF THE SLOPE

2.1 *FE 2D model*

The slope stability analysis is made with finite element software Plaxis. The geometry and the layers are given in figure 3. For the calculation of sliding slopes should be distinguish the existing slides as well as those caused by changes in loading, reduction of parameters so first time slides. In finite element numerical calculations for the new slide slopes can not predefined a critical surface along its length the strength mobilized parameters progressively softened. The problem must pass in two stages, initially determining a critical sliding plan (if any) and then to give the soil strength mobilized parameters of this plan the residual parameters.

Through the first model we can determine the stability of the slope for a long time while the second model we can define the engineering measures (walls, piles, anchored wires, nails, etc.) and make the their design.

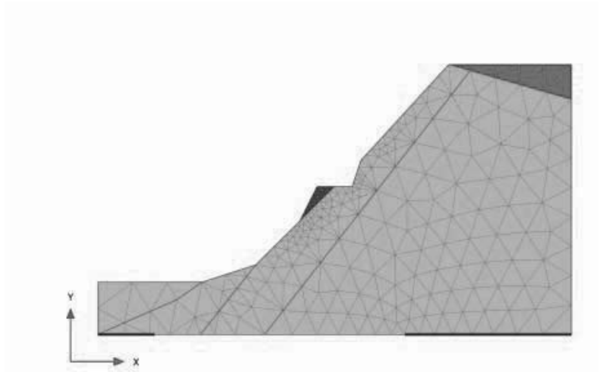

Figure 3. FE model of the slope

The soil is modeled as elasto-plastic material with yield criterion of Mohr-Coulomb. Advanced models with softening behavior would be more appropriate, but for lack of data (as well as the impossibility of accurate assessment of softening process) in our case can not be used. Weathering processes have been taken into account by dividing a surface layer in which the strength parameters gradually increase in depth until intact rock/soil values. In each analysis we took into account the initial natural stages as well as the following stages during the construction and the final stage during exploitation.

Influence of time, the accumulation of deformation, creep, brittle behavior that manifest same old overconsolidated clays, the formation of shear bands, influence of existing fissures, change of resistant parameters along the extent of the critical sliding surface, etc. in our model can not be taken in consideration. However, this modeling by taking the average parameters gives us practical results for the controls of the slope stability and dimensioning of retaining structures in the final limit state of the slope.

The fillings for road widening are reinforced with geogrids. Slope nailed wire mesh, anchors are simulated by applying a surface pressure perpendicular to the slope. The value of the pressure is taken such that the safety coefficient of the second model after application of this pressure to be 1.25. Plaxis program allows a sensivity analysis to see the influence of each parameter to the stability of the slope.

2.2 *Water influence*

The zone is one of the wetest zone in Albania with a average rainfall of 1750mm/year. It is well known that the rainfall precipitation degrade the soil properties due to progressive weathering. The weathered soil material has filled the longitudional channel blocking the dewatering. The water infiltrate through existing fissures reducing significantly the soil parameters. The flysch/old clay formation have been separated into two soil layers. Upper surface layer that has been weakened as a result of rain water infiltrations and bottom layer of the terrain representing the intact formation. We haven't used an underground water level and thus a seepage calculation because in this type of formation we can not speak for a real water level. The water influence is taken into account only between the reduction of surface layer parameters and increase of the thickness of this layer at the end of the excavated slope, toe of the slope. For the surface layer geotechnical parameters that are used are the residual parameters c_r, F_r.

2.3 *Seismic input*

One of the reasons of slope instabilities are seismic events. So for the long term stability in the seismic zones is necessary to do also slope seismic loads analysis. Seismic input can be considered from time history of acceleration. These time histories can be produced artificially or taken from records. In every case the accelerograms must be compatible with the acceleration spectra required by the codes.

For seismological and geotechnical applications real accelerograms are preferred because they are more realistic for frequency content, number of cycles, correct correlation between the vertical and horizontal components of ground motion and for the energy content in relation to the seismogenic parameters. In our case the site is near the zone of a seismic source that can generate earthquakes so we need to consider also near fault influence. However, in order to use a real accelerogram in near-fault conditions it is required for the time histories to include directivity effects and fling step, in other words they should refer to real, near-field earthquakes. So just for comparing the results we have also generated an artificial accelerogram taking account the near source effects.

Considering that we have been interested for the design of slope retaining structures the chosen accelerogram according to EC8 spectra is multiply by 2*1.4/1.146≈ 2.45 for being compatible with PGA taken from PSH analysis for T_R≈475 years. The ground motion parameters are given below:

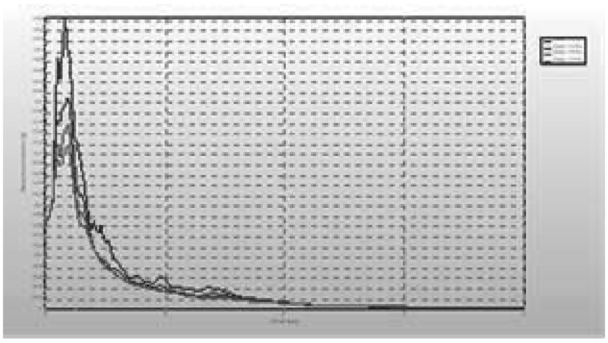

Figure 4. Acceleration response spectras

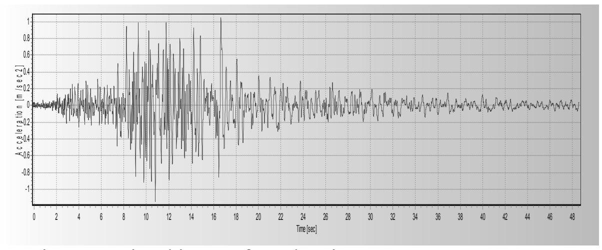

Figure 5. Time history of acceleration

PGA : 1.146m/sec2 in t=10.790sec
PGV : 0.082m/sec in t=16.590sec
PGD: 0.020m in t=47.880sec
Vmax / Amax: 0.071sec. Predominant Period (Tp): 0.300sec

2.4 *Results*

From the analysis is seen that local instabilities occur before global instabilities. To overcome this problem the filling reinforcement with geogrids have been activated from the first stage of excavation before defining the critical sliding surface. In figure 6 are given the displacement of the road body fillings.

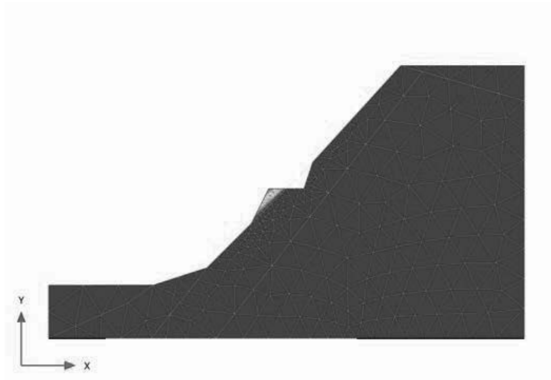

Figure 6. Local displacement

After that stage of local stabilization is done the global stability analysis. From analysis of the displacement and displacement incrementations we receive critical sliding surface shape and position as shown in Figure 7.

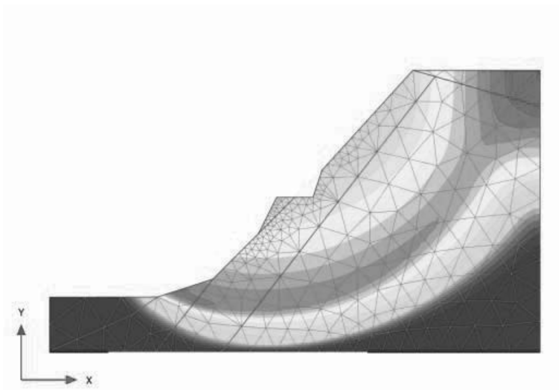

Figure 7. Total displacement

To simulate the critical sliding surface the "interface" element is activated with residual mechanical characteristics, c_r=5kPa, $F_r = 10^o$

Since in site are not observed existing deep slides that affect the global stability of the slope conditioning the preexisting sliding surfaces the value of cohesion is not taken zero, thus improving also the numerical calculations The displacement rate effect on residual strength parameters especially for seismic loading aren't taken in consideration.

In the case of application of a seismic load the safety coefficient for the second model decrease and wire anchored mesh of the slope should be strengthened, although for this case the coefficient of security can be taken close to 1. By sensitivity analysis of the parameters the cohesion changes are within small limits and their small changes doesn't affect the stability of the slope. The friction angle changes from peak values in those residual gives the greatest impact. These assessments we think correspond with the real monitored cases referred in literature. Since in the site is not implemented the wire anchored mesh the monitoring of weathering processes of slope materials in the future will give us the opportunity to correct resistance parameters values taken in the first analysis and reanalyze the slope stability.

3 CONCLUSIONS

Although the lack of data and the inability of finite element software with elasto-plastic modeling with Mohr-Coulomb yield criteria or softening criteria, to take into account the numerous elements that affect the stability of slopes in soft rock / old clay the simulation of processes by means of two modeling even in the case of application of simple models of yield criteria gives practical good results for first time slides ultimate stage or when we have a reactivation of an existing surface of non-brutal slide. This modeling does not provide intermediate data for the developed process, giving the possibility to correct in time the analysis parameters, and provide in time appropriate engineering measures. In any case when it will be used it will be referred only to the final phase with residual parameters.

4 ACKNOWLEDGEMENTS

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5 REFERENCES

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