Typology of landslides, investigation and monitoring in flysch deposits in Albania
Typologie des glissements de terrain, enquêtes et surveillance dans les dépots de flysch en Albanie

Skender Allkja, Ardita Malaj
ALTEA & Geostudio 2000, Albania, skender.allkja@alteageostudio.com, ardita.malaj@alteageostudio.com

Luljeta Bozo
Polis University, Albania, lulibozo@gmail.com
Lorena Harizaj
ALTEA & Geostudio 2000, Albania, lorena.harizaj@alteageostudio.com
Besian Xhagolli
ALTEA & Geostudio 2000, Albania, besian.xhagolli@alteageostudio.com
Ani Kosho
Devoll Hydropower, Albania, ani.kosho@devollhydropower.al

ABSTRACT: The development of infrastructure, energy and tourism in recent years in Albania has brought the necessity of geotechnical studies to a higher technical level. Most of these buildings (hydropower, motorway, pipeline) are built in mountainous areas with complicated geological conditions. The most complicated obstacles seem to be huge landslides, especially for those situated on flysch deposits. Most of the huge landslides were innate and active by the end of Pleistocene; however, some of them, especially those in flysch areas, are activated due to recent changes of climate and intensive man activities. Examples of re-activation of old landslides are encountered on Qukes-Qafe Plloçe road, on Devoll river valley where are being built several hydropower and on Poliçan-Potom area where is built a gas line. These landslides are under design investigations using field and laboratory methods like drilling, inclinometers and piezometers measurement, geophysical probing, rock and soil testing. All slopes with flysch rocks in Albania have low stability because of the presence of active landslides. In any case they should be studied using advanced geotechnical methods and monitored for long time in order to take the right protective measures.

RÉSUMÉ : Le développement des infrastructures, de l'énergie et du tourisme ces dernières années en Albanie ont mis en avant la nécessité d'études géotechniques de haut niveau technique. La hydroélectriques, autoroutes, pipelines sont construites dans des régions montagneuses avec des contextes géologiques compliqués. Les obstacles les plus compliqués semblent être d'immenses glissements de terrains, et plus spécialement ceux dans les dépots de flysch. La plupart de ces glissements se sont formés et ont été actifs jusque la fin du Pléistocene; cependant certains d'entre eux, surtout ceux dans les zones de flysch, sont activé suite à de récents changements climatiques et à l'activité humaine. Des exemples de ré-activation d'anciens glissements sont rencontrés sur la route Qukes – Qafe Plloçe, dans la vallée de la rivière Devoll où sont construites plusieurs centrales hydroélectriques et dans la zone de Poliçan-Potom où est contruit un gazoduc. Ces exemples font l'objet de cette publication. Ces glissements sont actuellement instrumentés et suivis via des essais de laboratoires et mesures in-situ (forages, inclinomètres, suivi piézomètrique, mesures géophysiques, essais sur roches et sols). Ils doivent être étudiés en utilisant des méthodes géotechniques avancées et surveillés pendant longtemps afin de prendre les mesures de protection appropriées.

KEYWORDS: inclinometers, landslide, monitoring, mudstone, sandstone.

1 INTRODUCTION.

The valleys (of Devolli & Osumi) mentioned in this paper are located in the central part of Albania. They cross the counrty from east to west.

Due to the numerous, important, engineering projects, such as: roads, hydro-electrical power stations and an international gas pipeline, various detailed geological and geotechnical studies, have been undertaken, for these regions.

The region of Devolli & Osumi valley, is composed of flysch rock, from the top, down to the bottom of the valleys. The flysch rock mass is characterized by lithological heterogeneity, due to the frequent vertical and lateral alternation of the different lithological sequences.

These valleys have developed from the ever-changing physical & geological, phenomena.

The hydropower stations, roads, pipelines that are built as well as any future project that will be built in this region, are threatened by different landslides that are present, active or about to become active.

This paper will describe and discuss case studies of landslide occurrences, the geotechnical properties of the materials of which the slope are composed of, as well as the analyses and the remedial works undertaken and necessary to stop the sliding.

2 GEOTECHNICAL PROPERTIES OF THE LANDSLIDES IN DEVOLLI RIVER & OSUMI RIVER VALLEY.

In order to determine the geological setting, the landslide dimensions and the position of the slip surface, geotechnical investigation and works were performed.

For all risked or active areas, geological mapping and borehole investigation was conducted, reaching down to bedrock formation, where disturbed and undisturbed samples were taken. In the aforementioned BH, inclinometers and piezometers were installed, in order to monitor the movement for a long period of time and laboratory tests were conducted for the characterization of the geological layers that were present in each of the studied landslides.

3 GEOLOGICAL SETTING & MORPHOGENESIS OF THE SLOPES AT DEVOLLI & OSUMI VALLEYS.

The valleys of Devolli and Osumi, are “U” and “V” shape valleys, with very steep slopes. The slopes are covered with bushes and high woodland, but there are also big areas of the slopes, which are stripped of vegetation. The outcrop of the landslide is visible and a number of houses were built there, some of which were destroyed by the slope movements. The slopes are transformed into agricultural lands. They are deformed and exhibit clearly visible bumps and holes. The most distinct and visible geological and geodynamical phenomena observed in these valleys, are:
Erosion; weathering; collapse and slide of the covering strata and of the core formation; tectonic faults and old landslides

The following deposits, are found in this region:

Deposits of Palaeogene (Pg_2^2; Pg_3^1; Pg_3^2; Pg_3^3). They are flysch deposits, composed of Mudstone and Sandstone. They have brown to beige colour, medium to weak cementation and their superficial part is weathered. Generally, they form unstable slopes.

Deposits on Neocene (N_1; N_3)

They are composed of Mudstone and Sandstone. They have brown to beige colour, medium to weak cementation and their superficial part is weathered. Generally, they form unstable slopes.

Holocene Deposits

Due to the formation process, these deposits are divided into alluvial ones, torrent ones and colluviums deposits.

4 TYPICAL LANDSLIDES IN DEVOLL’S AND OSUM’S VALLEY.

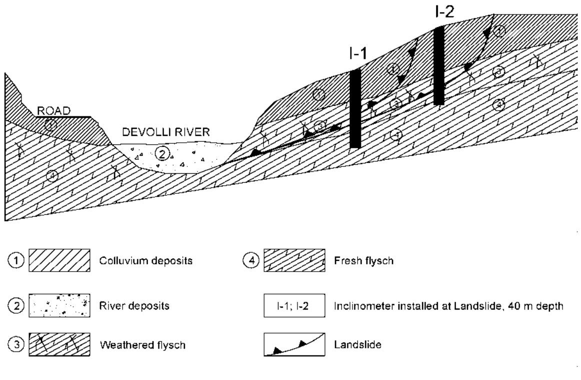

Figure 1. Landslides covered by colluvium deposits, where the dip angle of the rock layers, is in the direction of the slope of the valley.

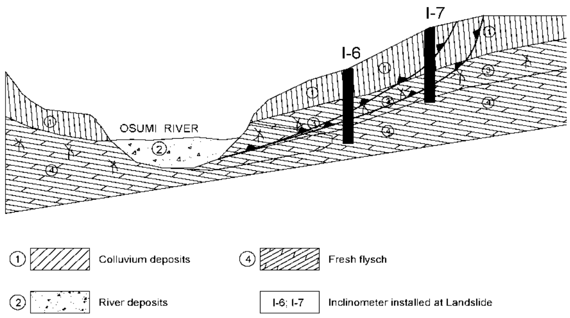

Figure 2. Landslides covered by colluvium deposits, where the dip angle of the rock layers is in the opposite direction of the slope of the valley.

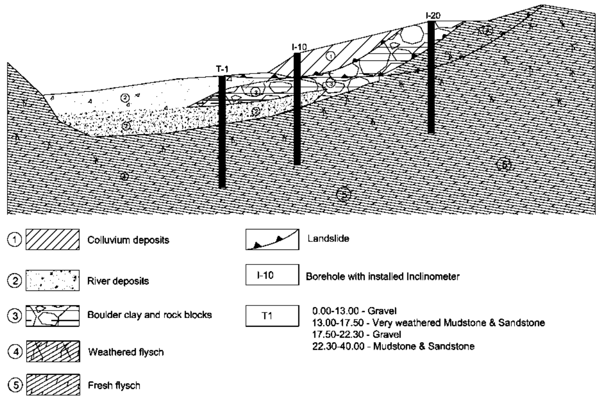

Figure 3. Landslides activated by imbalances of the slope as a result of river erosion.

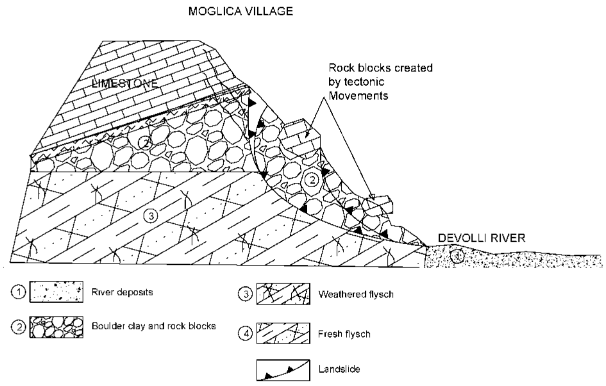

Figure 4. Landslides activated at the tectonic contact between strong and weak rock.

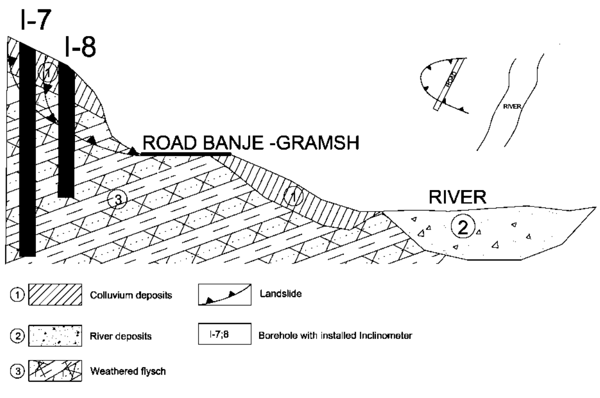

Figure 5. Landslides created by big unsupported excavations, during road construction or other objects.

5 LANDSLIDE DESCRIPTION IN DEVOLL’S AND OSUM’S VALLEY.

During the morphological evolution of these slopes, in previously formed depressions, the accumulated material was formed by physical and chemical weathering and was partly brought by gravitation, from hypsometrically higher parts of the slopes, to the bottom of the slopes.

Due to the different erosion intensity, that resulted as the consequence of variable climate conditions and energy of the relieve, the colluvium deposits of the cover strata are lithologicaly heterogeneous. That resulted in different filtration systems and different shear strength on the slopes.

These landslides were of multiple regression types and the sliding process developed from the bottom, up to the top of the slopes, causing further sliding on the slopes. These landslides were researched by the authors of these papers for several years. (A.L.T.E.A & Geostudio 2000, 2009-2016. Miscellaneous geological reports prepared for Devolli valley and Osumi valley).

6 RESULTS OF THE LANDSLIDES CASE-STUDIES IN THE VALLEY OF DEVOLL.

These landslides are studied in their dynamic movement, with respect to time and weather conditions. The target of each study in the landslide areas, in the valley of Devoll and Osum, is different and is described in detail separately, below.

6.1 *The results of Devoll's valley landslide case.*

As was described above, two large dams and some roads, were designed and built in the aforementioned valley.

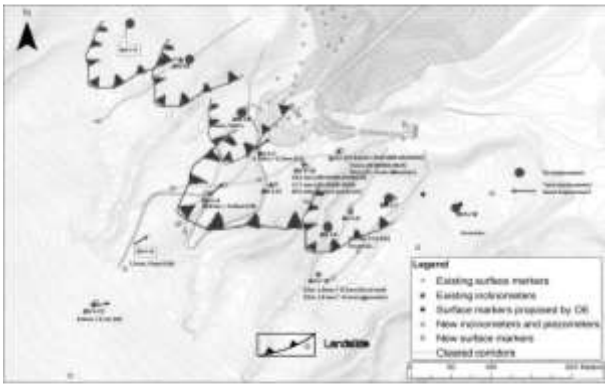

Figure 7. Landslide at Banja dam.

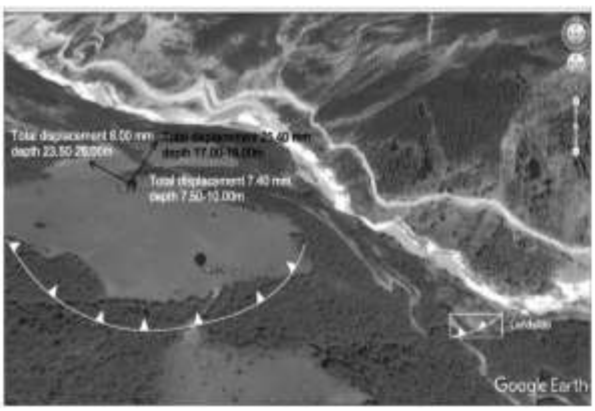

Figure 8. Landslide at Moglica dam.

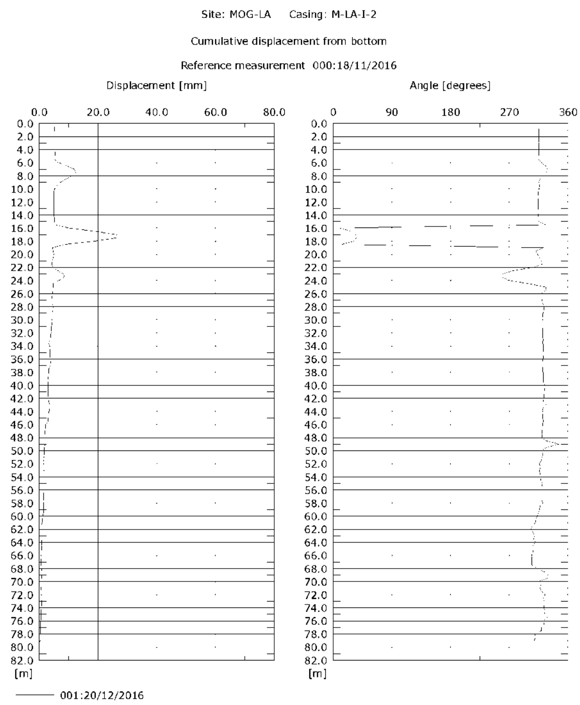

Figure 9. Cumulative displacement of Inclinometer measurement at Moglica dam.

The landslides at road axis, resulted by excavations during the construction of the road and there were also some existent old landslides, with small dimensions. From the test results conducted in the field and in the laboratory, there have been taken engineering measures, which have been effective.

From the 2-year monitoring period, results that, these landslides have been stabilized.

The landslides located near the large dams and reservoirs have big dimensions. The target in these landslide areas, is to evaluate the hazard created by movement of big soil masses, directly in the reservoir. The landslide hazards, near the dams, are evaluated and protective measures are taken. Although these measures include long time monitoring, for each movement, extra protective measures are needed, in addition to the calculations made.

No remedial works are undertaken for the stabilization of these landslides, but the potential soil mass that may slide into the reservoir is estimated, along with the released energy and the impact that they will have on the water level of the lake and this is calculated later on, during the design phase, as a safety height of the dam, over the maximal water quota in the lake. These landslides are being studied for their dynamic movement with respect to time and weather conditions.

Monitoring has given good results, but if any water level changes occur, they will be studied thoroughly.

6.2 T*he results of Osum's valley landslide case.*

As was described above, in the Osum's valley, one gas pipeline and some access roads are built.

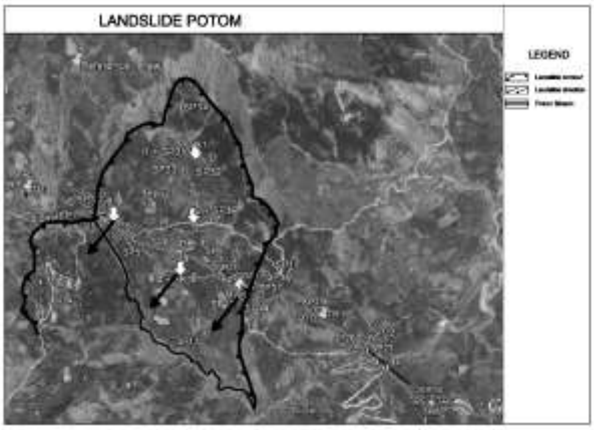

Figure 10. Landslide at Potom area, Osumi valley.

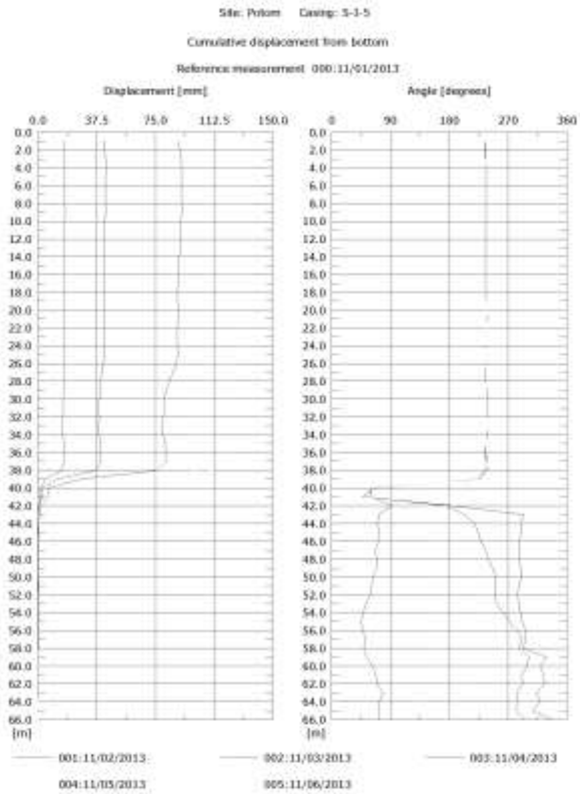

Figure 11. Cumulative displacement of Inclinometer measurement at Potom landslide area.

The landslides at road axis, resulted by excavations during the construction of the road and there are also some existent old landslides, with small dimensions. From the test results conducted in the field and in the laboratory, there have been taken measures, which have been effective.

From the 1-year monitoring period results that, these landslides have been stabilized.

The landslides located near the pipeline have big dimensions. These landslides are studied in detail and are monitored for two years. In the areas where the movement has been found to exceed the tolerance specified by the designer, there exist two types of solutions:

a. a non-existent sliding area is required.

b. the landslide size is evaluated and protective engineering measures are taken for the stabilization of the critical area.

In case (b), permanent monitoring will be needed in order to detect any new movement and additional protective measures also will be applied.

7 CONCLUSION

By the complex geological and geotechnical studies, that have been conducted in Devoll's and Osum's valley, there have been found certain types of flysch rock landslides, varying from a small to a large scale.

The movement of these masses of rocky soils, is dangerous for the existing facilities, or the ones that are to be built, therefore it is important to characterize the slides, the dynamic of their movement, the effective engineering and monitoring measures, that will limit, prevent or eliminate the sliding hazards.

It is recommended that for any new facility that will be built in these areas, a detailed geological and geotechnical study should be carried out.

The areas with low stability and the ones where old or new landslides might be active, are to be monitored during and after construction, in order to verify the effectiveness of the protective engineering measures.

8 ACKNOWLEDGEMENTS

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