Outlook on the Possibility for Slope Stability Evaluation According to Petrophysical and Integrated Geophysical Data

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Summary

Results of the geophysical data for in-situ evaluation of the physical-mechanical properties of the rocks in the unstable slopes in Albania are presented.

Introduction

Albania represents a mountainous country with complicated geology. There are unstable mountain and hill slopes. Developing of new landslides or re-activation of the old ones is mainly due to construction works. Special constructions, such as hydrotechnical works, civil, industrial, urban and rural constructions and constructions in the infrastructure, particularly during last years, as well as destroyed equilibrium in ecological systems through deforestation etc., all these events have contributed to landslide development. Landslides are located in the deluvial depositions, and in the altered-bedrock. The slipping bodies of some landslides have very big volume, more than 50 million cubic meters.

Hydrotechnical works in Albania are generally constructed in conditions of rugged terrain and in geological formations in which the land sliding phenomena are often present. There are observed active landslides in the lakeshores of hydroelectric power plants, which represent a great geological risk. Buildings have been destroyed in some villages and some people died in ruins. This phenomenon has been more evidently activated when hydrotechnical works started to be used. During the exploitation period of more than 25 years, the huge hydrotechnical works influenced the physical-mechanical properties in the shore area and caused a series of landslides. Analyze of the results of two landslide investigations, happened in different geologic conditions in the paper are presented. These typical landslides were developed at lakeshore of the Vau Dejes Lake and Fierza Lake of Hydropower Plants at Northern Albania. The yearly movements of water level at Vau Dejes and Porava lakes caused big landslides in eolated, weathered and destroyed rocks.

Integrated geophysical methodology for in-situ testing

Integrated geological-geophysical engineering and geodesic observations have been carried out for slope stability studies and monitoring of the active landslides in Albania. In-situ geophysical investigation and monitoring have been programmed in three phases:

1. Surface integrated geological-geophysical survey and installation of geodesic markers.
2. Drilling of shallow boreholes, cross-hole seismic survey and well logging.
3. Periodical geophysical and geodesic observations in boreholes and on the ground surface.

The basic method was the high frequency refraction seismic. Geophone setting in the survey line had distances from 0.5-43 meters, according to the object size and the required seismic depth investigation. The longitudinal and shear waves were recorded through the time intercept method. The natural seismic-acoustic activity inside and outside of slipping body has been observed for a continuous time of 5 seconds. Creating the seismic waves is performed by mechanical shock. A seismic 12-channel station ECHO-2 of Canadian Company SCINTREX was used for recording the seismic signals. The processing of records is made by the company's software package. The longitudinal waves velocity Vp, the shear waves velocity Vs and the layer thickness were calculated from the field data. The depth of the seismic investigation was about 25-27 m.

Electrical Schlumberger soundings and profiling have been performed to investigate and to monitor landslides. Electrical soundings were performed by the Schlumberger array, with spacing up to AB/2 = 500 m, which allowed to reach a survey depth of 120-150 m. Resistivity tomography was performed by multiple Schlumberger arrays with different investigation depths, relating to the required depth of investigation for each object.

Together with the geophysical methods mentioned above, the micro-magnetic and micro-gravity surveys were also applied in some landslides. The hole-hole seismic tomography of longitudinal and shear waves, the gamma-

gamma density logging, neutron-gamma logging, electrical logging, acoustic logging and inclinometers have been applied in boreholes.

Samples of soil and rocks from the studied area were analyzed in the laboratory for determination of their physical-mechanical properties and for further petrological studies of thin sections.

The study of the shape and structure of the slipping body, estimation of physical-mechanical properties of the slipping body and of the bedrock, and evaluation of the level of the landslide natural seismic-acoustic activity were carried out using the results based on the interpretation of geophysical surveys. Physical-mechanical properties of rocks in the surrounding area have documented their important role in relation to the slipping body mapping, study of slope stability and dynamics of the landslide's development.

Analysis of results

Ragami landslide is located in the shores of the Vau Dejes Lake. It is developed in the ophiolitic formation represented by serpentinized rocks. The slipping body represents a big mass of serpentinite, which is eolien, destroyed and covered by a thin layer of diluvium. According to the geological survey in 1992, the landslide did not exist. Landslide has been significantly developed during the last ten years. Slipping body increased in the extent and in the volume substantially during this period. The front part of the slipping body is located along the shores of the lake. This part has the shape of a scarp about 2 -3 m high, and represents a destroyed, schistose serpentinites, partly in a form of mylonite. Three failures in different superficial levels can be observed in this landslide:

- The first one 35 - 45 m from the shore, with a horizontal dislocation of about 2 m.
- The second one about 70 - 90 m from the shore, with a vertical jump of about 2 m.
- The third one about 115 - 130 m from the shore. This is the newest level and has the lowest amplitude.

The integrated engineering geophysical section of the slipping body is presented in Figure 1. Two main sliding plains separate this body. The rock material of plains is broken up.

The first plain is at depths of 5 - 7 m, while the second one reaches depth up to 22 m. The lowest part of the second plain touches the lake under the water level. In this way, the sliding body has a block-type character.

The physical-mechanical properties of the slipping body are lower than those of the basement rocks, not touched by the sliding phenomena. The micro movements in the slipping body are very intensive and have a wide frequency band, while outside the body no movement activity is observed.

Physical-mechanical properties of rocks in the area of Ragami Landslide are presented in Tables 1 and 2.

As documented in Tables 1 and 2, four layers with different physical-mechanical properties create the slipping

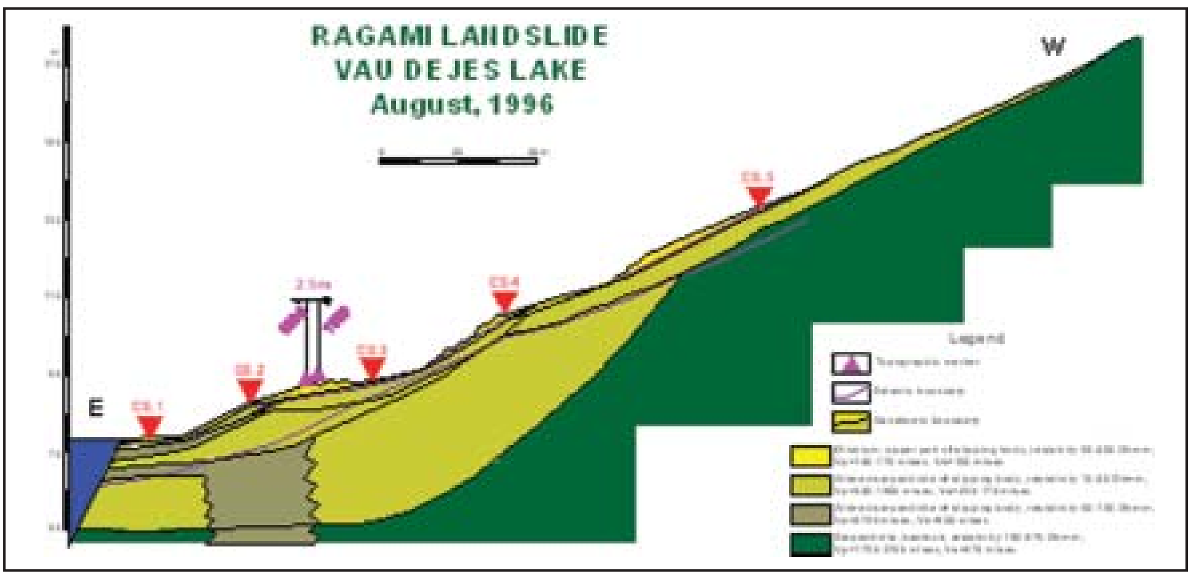


Fig. 1: Engineering integrated geophysical section of the Ragami landslide.

Table 1 : Physical Properties Of The Rocks In Landslide's Area

Layer Number	Thickness, in meters	Resistivity in Ohmm	Density,in g/cm^3	Wave Velocity, in m/sec Vp	Vs	Lithology
				SLIPPING BODY		
1	0.7	76.4	1.34	210	160	Deluvium
2	4.0	29.5	1.61	540	230	Breaking serpentinite
3	6.5	46.5	2.45	3700	680	Water-bearing serpentinite,
4	17.4			1500		Breaking serpentinite
				BED ROCKS		
		485	2.56	3500	1920	Serpentinite

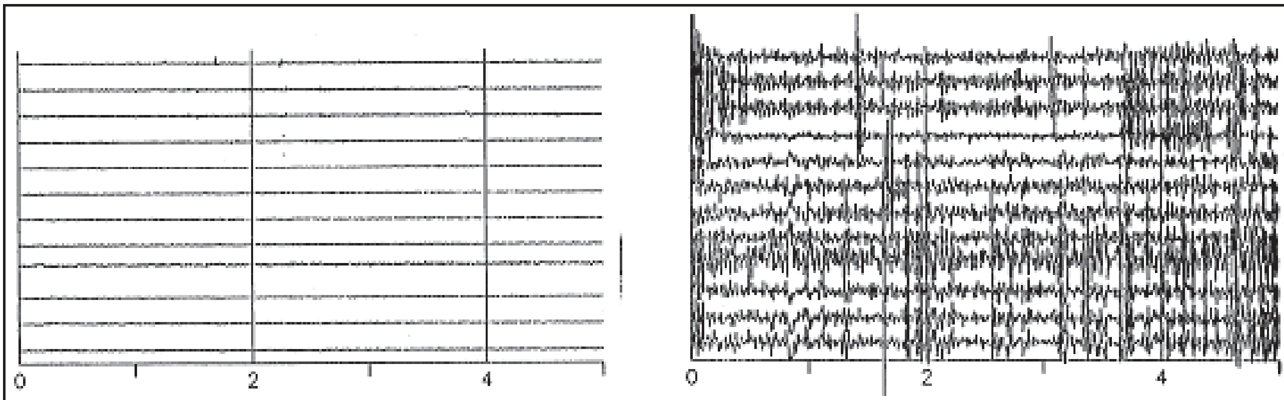
Table 2 : Mechanical Properties Of The Rocks In Landslide's Area

Layer Number	Poisson's Ratio	Dynamic Elasticity Modulus, E_d^sin $*10^5$ $kg/cm^2$by V_s values	Rigidity Modulus G,in $*10^5$ kg/cm^2	VolumeConstrain, σ,in $*10^5$ kg/cm^2	Rock's state
			SLIPPING BODY		
1	0.35	0.00370	0.00140	0.00420	soft rocks
2	0.39	0.02413	0.00868	0.03630	Destroyed, shattered rocks
3	0.48	0.56586	0.19167	3.26503	Cleavages and fissured rocks
4		0.26325	0.09608		Destroyed, shattered rocks
			BED ROCKS		
	0.29	2.46271	0.96199	1.91408	Compact rocks

body. First layer represents the deluvial cover. Layers 2 and 4 are represented by destroyed-shattered serpentinites. The third layer in between is characterized by low electrical resistivity and low shear waves velocity. It corresponds to the water saturated cleavages and fissures in the serpentinites.

The dynamics of slope movement is also reflected in the natural seismic-acoustic activity. The micro-movements in the slipping body are very intensive and have a wide frequency band. No movement activity is observed outside the slipping body (Fig. 2).

Porava landslide on Fierza Hydropower Plant lakeshore is developed, at northern Albania Porava village. In fig.3 is shown the detailed geoelectrical section of the landslide. There were fixed two categories of geoelectrical boundaries. The primary category belongs to the lower contact, at 140-160 m depth and the upper at 20 m depth, which separated rocks with different electrical properties. The lower boundary is the major boundary, which separated the slipping body from the main sedimentary-volcanic rocks. It is the geoelectrical marker that clearly envisages the



Outside of slipping body

Inside of slipping body

Fig. 2: Natural seismic-acoustic activity in the Ragami landslide area

bottom of the slipping body. As a result of the slipping phenomena, these rocks have low up to medium electrical resistivity value (200-100 Ohmm). While the rock located under the whole massive slipping body have higher electrical resistivity values (in the farthest sector of the profile in the lake side 3000-3800 Ohmm and 1200-1400 Ohmm in the sector located near the artificial lake of Fierza Hydropower Plant). The upper boundary separated the slipping body into two big layers. The most upper part of this slipping body represented by the deluvial- eluvial depositions, is very active today and has very low resistivity values (120-500 Ohmm). This part is in continuous intensive movement, causing big damages for the houses of Porava village. The second category of boundaries is linked to the changes at heterogeneity in falling of slipping body, which is separated into blocks.

In fig.4 is shown the seismic section of the same profile in Porava. This section envisages the same elements as well as the geoelectrical markers. Deluvial-eluvial depositions have low seismic waves velocity Vp=400-1200m/s and Vs=150-450 m/s. Volcanic rocks of the slipping body have e velocity Vp=1050-3800m/s and Vs=550-1500 m/s. According to these data, the physical-mechanical parameters of soils and rocks were evaluated (Tab. 3).

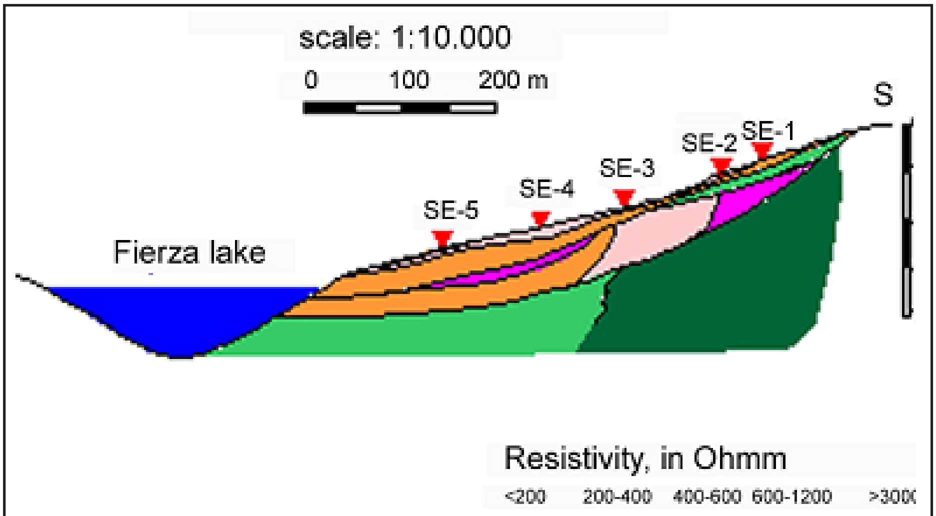


Fig. 3. Geoelectrical section, Porava Landslide

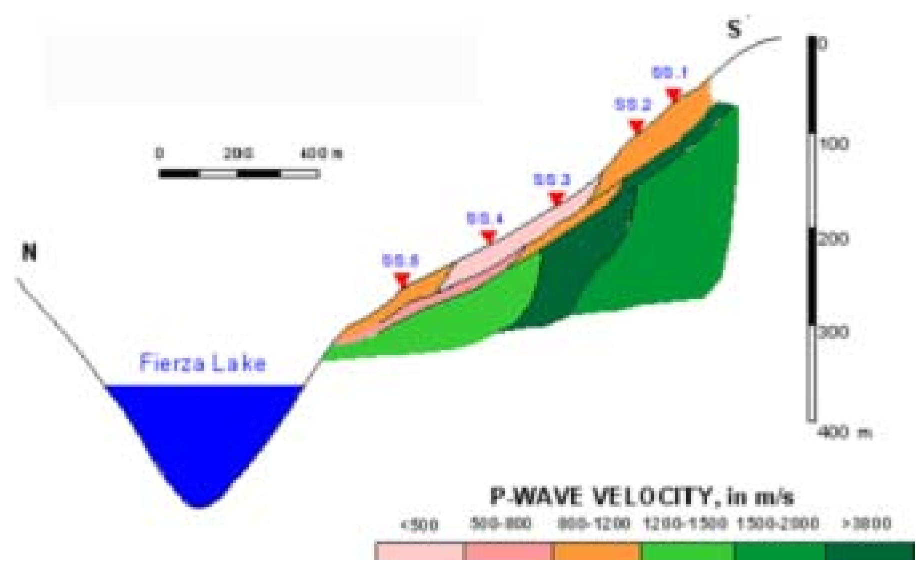


Fig. 4: Seismic section, Porava Landslide

Table 3: Mechanical Properties Of The Rocks In Porava Slipping Body

Layer		Wave Velocity, in m/s		Density ρ	Puasson's Ratio	Dynamic Elasticity Modulus, E_d^s $x10^5KG/cm^2$ by V_s values	Rigidity Modulus, G in $x10^5KG/cm^2$	Bulk Modulus, in $x10^5KG/cm^2$	Volume Constrain, σ, in $x10^5KG/cm^2$
Nr	H,m	V_p	V_s	g/cm^2					
1	2.9	400	200	1.53	0.33	0.02	0.006	0.02	0.02
2	6.4	600	400	1.44	0.1	0.06	0.03	0.02	0.02
3	11.5	1050	580	1.92	0.28	0.17	0.07	0.13	0.13
4		176	940	2.15	0.30	0.45	0.17	0.38	0.38

Conclusions

1. Geophysical-engineering studies have a triple character: a) to study the soil of the landslide area, b) evaluation of in-situ physical-mechanical properties of soils and rocks and c) in-situ monitoring of landslide phenomena.

2. Landslide on shores of the Fierza Lake at Porava village represents of big thick and volume slipping body. Blocks with many layers construct them.

3. Thick and high volume slipping bodies represent the Ragami active landslide in the shore area of the Vau Dejes Lake.

4. Slipping body of the Porava Lanslide is characterized by the presence of two categories of geophysical boundaries. The primary category belongs to the lower contact, at 140-160 m depth and the upper at 20 m depth, which separated rocks with different physical-mechanical properties. The lower boundary is the major boundary, which separated the slipping body from the main sedimentary-volcanic rocks. Upper part of this slipping body represented by the deluvial-eluvial depositions.

5. Both landslides are active._The block-like character of the sliding bodies brings to the conclusion that the block of these bodies cannot fall down immediately in any kind of velocity.

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