Skavica Hydropower plant, one of the most important energetical projects to be constructed in Albania

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ABSTRACT: Skavica area is in the north-eastern part of Albania. This article aims to characterize the soils and rocks met in the area under study following the national and international building codes and standards, focusing on the characterizations of rock formations.
The main works for the geological and geotechnical study for Skavica HPP project, included the data received recently from A.L.T.E.A. & Geostudio 2000 company investigation. These works comprised a careful geological mapping; geological drillings; trial pits; sampling; field testing (SPT, Lugeon test, Le franc test, borehole optical readings, seismic measurements including refraction and reflection measurements; geophysical measurements, electrical measurements etc...); laboratory testing.
This article will present and include all of the findings of our study; the interpretation of field and laboratory testing results and recommendations of the engineering measures to be taken to ensure dam stability and reservoir water conservation.

Keywords: geological investigation, rock formation, rock characterization, field testing, laboratory testing, dam stability.

1 INTRODUCTION

The Skavica hydropower plant is predicted to be built on the valley of the Black Drini river. This valley in the major part has the "V" shape terrain and occasionally it appears as a "U" shaped landscape. The slopes of the valley are very steep and are partly covered with shrubs or tall trees now and then.

The slopes where the limestone rocks are present are very steep and almost without vegetation. In these areas are identified karst cavities. Slopes where other rocks formations are present are slightly steep and covered with vegetation.

The hydroelectric dam is proposed to be designed in the narrowest axis of the area under investigation. To have a closer look on the geological features of the area, geological drillings were arranged and planned to be performed. To access the drilling points was very difficult, and the construction of access roads was a must. Some of the main works included:

- Access roads preparation for the drilling rigs, a total of 15 km was constructed in the area of Skavica.
- Drillings were carried out with continuous sampling to a depth from 50.00m up to 350.00 m, with a total drilling of 3299.60 m were carried out.
- Trial pits with depth 3.50-4.50 m
- Lugeon tests (379)
- Lefranc test (23)
- SPT test (403)
- Seismic refraction tests 50 SRF lines of over 5000m
- Electrical measurements of over 1300m
- Seismic reflection test (approx. 5000 linear meters),
- P-S velocity test (12 Boreholes)
- OPTV tests (over 1000 linear meters)
- ATV tests (over 500 linear meters)
- Monitoring, (for this purpose there are installed open tube piezometer and FGT)
- Laboratory testing, for determination of the physical geotechnical parameters on soil and rock samples.

2 GEOLOGICAL STRUCTURE

After a careful desk study, and geological surveys in the construction field, the following rock types:

- Limestone rock

Moderately strong, grey to beige, very fractured Limestone. As a result of tectonic movements, the rocks are cracked in some cases there are weak areas that create unstable slopes.

- Metamorphosed//metamorphic clays (schist)

Moderately weak to moderately strong, beige, brown and grey fractured Schist. The upper part of this formation is weathered. These rocks form unstable slopes.

- Colluvium deposits

composed by firm to stiff, brown to beige, silty CLAY, containing gravel and boulders.
For a more detailed look please refer to the figure below

2.1 Physical, Geological, and Geodynamic Features

Based on previous and recent data, the main geological phenomena and geodynamic features characterizing the geological formations encountered at this area are:

- Weathering.
- Consolidation of the alluvial and colluvium deposits.
- Karst phenomena in the limestone rocks.
- The movement and sliding of the colluvium covering masses and of the most weathered part of the bedrock formation in the downfall direction.
- Tectonic activity.

Description of these phenomena one by one below:

- Weathering phenomenon, visible on the root formations composed of claystone, sandstone and conglomerates. These are soft rocks, with a weak clayey matrix, which

under the action of atmospheric agents, turn into soils. This phenomenon is most visible at the area, where shale deposits are present.

- Consolidation of the alluvial and colluvium deposits. The alluvium deposits of Drini River are composed by silty clay, sand, and gravelly layers. During the decomposition process, these soil changes its volume and causes an immediate settlement that influences negatively on the stability of the objects placed on these layers. In the studied area, these layers are present (from natural surface up to approximately 5.00 m deep). A special attention must be paid to the design of the foundations of the new objects of HPP Skavica, regarding these deposits' behavior.
- Karst phenomena are present in limestone rock formations. Previous existing geological studies performed during a long period of time in Skavica area have proved that the karst phenomena are very developed on the limestone rocks. As we mentioned above, in many cases, karstic caves of big sizes have been discovered. Under these conditions, we recommend that the dam area and its sides insulate the water and not infiltrate outside the lake, constructed to produce electrical power.
- Movement and sliding of the colluvium covering masses and the most weathered part of the core formation in the direction of slopes downfall. This phenomenon is evident on both sides of the valley. There are present sandstone and mudstone rock formations. On these slopes are evident also large rock blocks, ready to move towards the bottom of the slope. Facing these conditions, engineering measures are necessary, so HPP Skavica's facilities are not threatened by these movements.
- Tectonic activity: Albania has a well-developed regional tectonic, which is mainly horizontal with low angle over thrust. From the studies of Albanian and foreign authors, it has been found that all eastern areas have moved (low angle over thrust) towards the west. This phenomenon has caused a destruction of rock masses. The regional tectonic is accompanied by many other local tectonics, which are present in the area where the objects of Skavica HPP will be built. These areas are found in the contacts between different type of rocks or within the same type. As a result, many rocky masses have moved toward the bottom of the valley and have created a rocky bended landscape.

3 FIELD INVESTIGATION

Field works intended to determine in the site the characteristics of geological formations in the Skavica Dam area. During field work are taken samples with disturbed and undisturbed structures to be analyzed in the laboratory. In order to determine the quality of the rocks encountered in the area of the Skavica dam, the following works were carried out in the field:

1. Geological survey: mapping, drilling, trial pits
2. Sampling
3. Geophysical survey: refraction, reflection, electrical measurements, P-S velocity logging
4. Optical and acoustical borehole televiewer
5. Permeability test: Lugeon test on rocks and falling and constant head for soil deposits; Le Franc testing.
6. Rock and rock mass description
7. Site point load test
8. SPT testing
9. Water level monitoring

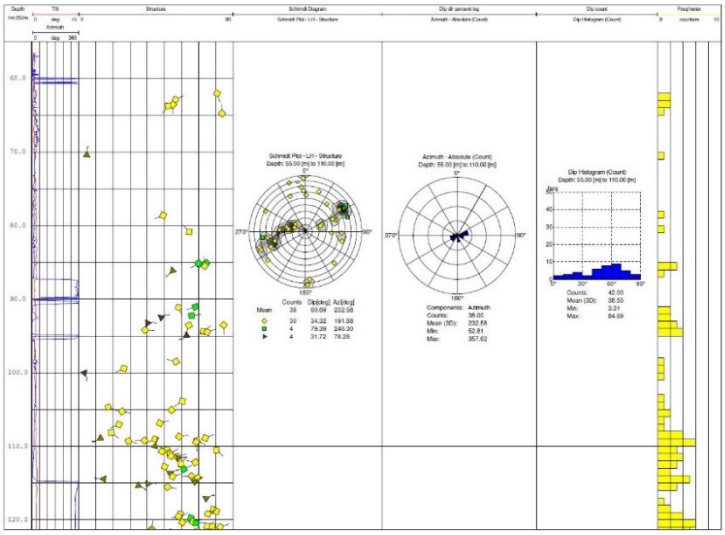

Figure 1. Optical and acoustic televiewer investigation sample (A.L.T.E.A & GEOSTUDIO 2000).

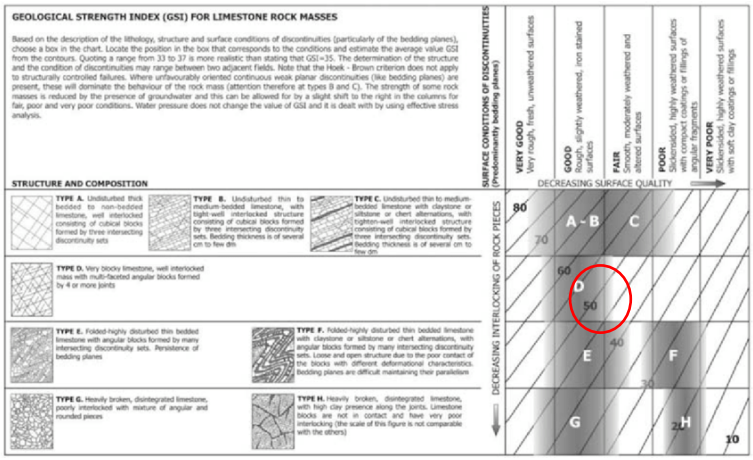

Figure 2. Geological strength index, GSI-classification chart for limestone rock masses (Marinos (2010). New proposed GSI classification charts for weak or complex rock masses. Bulletin of the Geological Society of Greece, 43, 1248-1258).

4 LABORATORY TESTING

This section presents the laboratory test performed for Skavica dam study area. In addition to field testing, a very large number of laboratory tests were performed, such as the following:

- moisture content according to ASTM D 2216-19 Method B,
- bulk density according to ASTM D 7263-09 / Method A
- specific gravity according to ASTM D 854-14
- longitudinal and transversal sonic wave velocity on rock samples according to the ISRM-1978-ASTM D2845.
- rock porosity according to ISRM-Suggested Method 1974- 2006
- point load test according to ASTM 5731 - 16
- basic friction angle according to ISRM 1974-2006
- splitting tensile strength of intact rock cores according to ASTM D 3967-16
- unconfined compression test with modulus according to ISRM 1974-2006
- multiple failure triaxial compression strength and elastic moduli according to ISRM-1978 - 1983 - ASTM D7012-2010 - Turk & Dearman, 1986

5 IN-SITU AND LABORATORY CHARACTERIZATION OF ROCKS

Below are represented some tables and figures from the tested rock specimens carried at Dam area.

Table 1. Characterization of joint sets.

Joint set		J	J1	J2	J3
Orientation	[°]	070/35	133/65	90/45	120/60
Spacing	[cm]	18	43	38	55
Roughness	[JRC]	8-10	10-12	6-8	4-6
Strength joint wall		MS	W	W	W.
Weathering	[W]	SW	MW	MW	MW
Aperture	[mm]	0.5-2.5	0.25-0.5	0.5-2.5	0.5-2.50
Filling	[-]	No filling	clay	clay	clay

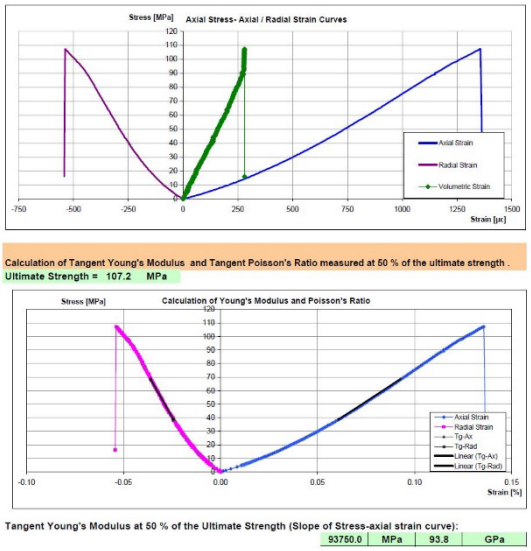

Figure 3. Graph representation of deformation testing on rock samples (ISRM-Suggested Method 1974-2006).

Table 2. Deformation properties of encountered rock formations at Dam area.

Description	UCS	Young's Modulus	Poisson's ratio
	MPa	GPa	
Weak Limestone	16	15	0.34
Moderately strong to strong Limestone	80	90.9	0.32
Shales	5	3.5	0.40

Grades of unconfined compressive strength are measured and classified according to ISRM method on the Classification of Rocks and Rock Masses 1981.

The values on the table, are the average values of more than 20 tested specimens.

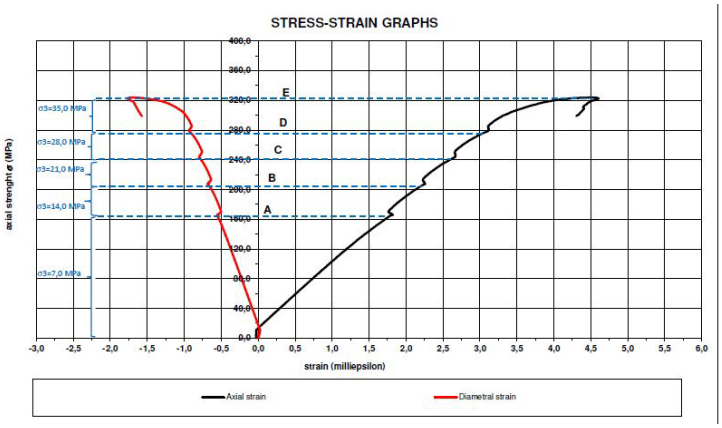

Figure 4. Graph representation of multiple failure triaxial compression strength and elastic moduli (ISRM-1978 - 1983 - ASTM D7012-2010 - Turk & Dearman, 1986).

6 CONCLUSIONS

Specific geological conditions have a huge impact on dam safety because they are sometimes accompanied by geological disasters. Two main problems are faced on the area of the Skavice dam:

- Dam stability and Storage of water in the reservoir

Rocks formations around the dam area, are fissured and the tectonic activity is very developed. In this case, the optimal proposed solution according to our expertise is a rock-fill dam type with a clay or asphalt core.

To preserve the water in the reservoir, it is necessary to take engineering measures for building an improved area under the dam and in its side parts to create an impermeable areas.

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