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MONITORING OF DAMS BY GEOPHYSICAL METHODS

A. Frashëri Faculty of Geology and Mining, Polytechnic University of Tirana, Albania

Abstract

Results of integrated civil engineering and geophysics investigations in the rock fill dams in Albania are presented in the lecture. Albania has numerous and biggest dams belonging to the hydroelectric power system. These dams are made of concrete and/or rock fill with central clay core. In Albania, in a short period of about 30 years, have been constructed also about 600 dams for the reservoirs of the irrigation system. The height of their clay dams varies among 10 and 40 meters, while the crest length of the dams goes up to 3 500 meters. Analyze is based on results of seismic and geoelectric tomography in two large dams of Hydroelectric Power Plants in Albania during the period 1995-1998. The results of these investigations and the technical data on the stability of the constructive materials and rocks can be used to apply the modern dynamic methods for re-estimation of the stability of the hydrotechnical construction.

1. INTRODUCTION

Albania has numerous and biggest dams belonging to the hydroelectric power system. These dams are made of concrete and/or rock fill with central clay core. Bigger hydrotechnical work in Albania, the Fierza Hydroelectro Power Plant, has an installed power of 500 MW. The volume of water in its artificial lake is 2.7 billion m³ (Hydropower Plant Executive Projects, 1953-1988). This hydrotechnical work composed of several constructions. The rock fill with central clay core dam is the biggest assemblage therein. The dam has a crest length of 500 meters and maximum height of 165 meters. In Albania also about 600 dams for the reservoirs of the irrigation system have been constructed. The height of their clay dams varies among 10 and 40 meters, while the crest length of the dams goes up to 3 500 meters.

The exploitation of hydrotechnical work over the last 15 to 40 year has influenced the modification of their physical- mechanical properties and constructive structure. Under present conditions, the re-estimation of the stability of the hydrotechnical construction was necessary. In this case, the acquisition of geophysical data on the stability of the constructive materials and rocks was very important in order to apply the modern dynamic methods of such re-estimation. These data must extract from the in-situ geophysical investigation, which had to go through the following steps (Frashëri A. et al., 1998 Frashëri A. 2004): 1. Investigation of constructed material, which the dam was build up:

1.1. Studies of the structure of the construction material,

1.2. Determination of physical-mechanical properties of the construction material,

1.3. Evaluation of physical-mechanical properties variation in times.

- 2. Estimation of slope stability and the study of landslides in the lakeside.
- 3. Investigation of the grout curtain under the dam in riverbed.
- 4. Estimation of the remnant deformations of the dams,
- 5. Monitoring of the dams.

Dam monitoring during their exploitation period has double tasks:

- 1. Non stop recording of the dam's micro-movements. In the dam must be installed axelerographs and geophones of different frequencies and sensitivity.
- 2. Periodical investigation of technical status of the dam.

Actually dam monitoring is performed by integrated modern methods. The geophysical surveys represent most important methods in this investigation complex. Classical surveys of underground water flow dynamic and status of mechanic stresses field is also important part of the monitoring methodic.

Large number of case histories from various objects is analyzed in this presentation.

2. GEOPHYSICAL METHODS

A complex of geophysical methods is possible to apply for in-situ investigation of the dams (Frashëri A. 2004, Frashëri A. et al., 1998, Robert C. Benson et al. 1983). Geophysical investigations have importance in the dam's monitoring complex, because:

- In-situ geophysical investigation is unique because is performed without any intervention in the dam construction.

- Geophysical methods are capable to realize the dam tomography.

- Have possibilities to determined dynamic physic-mechanical properties of the construction materials and bedrocks, ex. dynamic elasticity modulus, which are base parameters for use of modern estimation methods for evaluation of the technical status of the dam.

- By in-situ tests by geophysical-engineering methods, the physical-mechanic properties of constructed materials are evaluated for a large volume, thus they are more representative, and as a consequence the evaluations are made more appropriate and reliable than laboratory determination by small volume of separated samples. Certainly this does not mean that the laboratory tests are not necessary. They are of course necessary, limited to the size needed to define the relations between physical and mechanical properties of constructed materials, soil and rocks.

- Is possible for non-stop recording of some parameters, which are in the monitoring base.

- In-situ integral geophysical surveys are most cheaper methods for dam investigation and monitoring, i.e. a seismic sounding costs as much as 2 linear meters drilling made into

clay section, or as much as a quarter of meter made into the gravel and magmatic rocks. Electrical sounding's cost is about 25 % less than seismic soundings; meanwhile the depth of geophysical investigations is from some centimeters to tens of meters.

2.1. Shallow seismic of high frequencies. Seismic tomography of concrete between the galleries and dam couple surfaces in complex with the refraction seismic profiling at the dam surfaces and in galleries are main geophysical surveys. The quality of the grout curtain under the dam in the riverbed can investigate in-situ on the gallery floor. Offset of some meters up to 50 m, according to the object's size and the required depth of investigation must use for the seismic observation. Distance among the geophones can selected 0,5- 2 meters. Creation of the seismic waves is performed by mechanical source. We have used a seismic 12-channel station to carry out the recording. Data processing was made by the company's software package. According to the surveys' data the velocity of P-waves (Vp) and S- waves (Vs) were calculated, as well as the layer thickness. According to all the seismic data, the physical-mechanical properties were calculated for the soil, rocks and concrete of the dams such as Poisson coefficient, elasticity dynamic modulus of, Bulk modulus, rigidity modulus and compression volume strength modulus:

Poisson coefficient,

$$\nu = \frac{V_p^2 - 2V_s^2}{2(V_p^2 - V_s^p)}$$

Elasticity dynamic modulus,

$$E_{1} = \rho \cdot V_{p}^{2} \frac{(1+\nu) \cdot (1-2\nu)}{1-\nu} \cdot \frac{1}{10} \qquad \text{in} \left(\frac{N}{cm^{2}}\right)$$

$$E_{2} = \frac{1}{9.81} \cdot E_{1} \qquad \text{in} \left(\frac{KG}{cm^{2}}\right)$$

$$E_{3} = 10^{4} \cdot E_{1} \qquad \text{in} \left(\frac{N}{m^{2}} \rightarrow Paskal\right)$$

$$E_{4} = 2 \cdot \rho \cdot V_{s}^{2} \cdot \left(\frac{10^{-1}}{9.81}\right) \qquad \text{in} \left(\frac{KG}{cm^{2}}\right)$$

where: ρ - Dendsity, in (g/cm³)

 V_p , $V_s - P$ and S waves velocity, in (m/sec)

Elasticity static modulus, for cases $E \ge 2.5 \cdot 10^5 \frac{KG}{cm^2}$:

$$E_s = \frac{E_2 - 0.97 \cdot 10^5}{0.83}$$

Bulk Modulus,

$$K = \frac{E_2}{3(1-2\nu)} \cdot 10^5 \qquad \text{in} \left(\frac{KG}{cm^2}\right)$$

Rigidity modulus.

$$G = \frac{E_2}{2(1+\nu)} \cdot 10^5 \qquad \text{in} \left(\frac{KG}{cm^2}\right)$$

Compression volume strength modulus:

$$S = \rho \cdot \left(V_p^2 - \frac{4}{3} V_s^2 \right) \cdot \frac{10^{-6}}{9.81} \cdot 10^5 \qquad \text{in} \left(\frac{KG}{cm^2} \right)$$

Volume compresion:

$$\sigma_c = 123 \cdot V_p \cdot 10^{-3} - 109 \cdot V_p \cdot \alpha \cdot 10^{-3} - 148\alpha - 52.8$$

Where: α - waves absorption coefficient, in cm⁻¹

For the seismic waves with a frequencies f=100-500 Hz, this coefficient is determined by equation:

$$\alpha = \frac{1}{\ell_2 - \ell_1} \cdot \ell n \frac{A_1}{A_2}$$

where: A_1 , A_2 – seismic waves amplitudes, in cm

 ℓ_1, ℓ_2 - offset length, in cm

Concrete Mark

Concrete Mark (compression resistance) can be determined by formula:

$$R_{c4} = \frac{V_p^2 \cdot \rho_0}{140\rho} \cdot \left(\frac{1 - 2\nu}{1 - \nu}\right)^2$$

Where: ρ_0 - volume mass

 ρ - Density measured in samples

v - Poisson Coefficient

Vp- Longitudinal seismic waves velocity

Compression resistance R_{c4} , which was determined after seismic data, has been checked by laboratory determination in cubic samples R_{c3} , by data of the concrete preparation center R_{c2} , and also by project data R_{c1} .

The dynamics of dam's movement observed also through recording of the natural seismic-acoustic activity and micro-movements.

2.2. Geoelectrical tomography to investigate the clay core of the dam's raw materials is possible. Resistivity Real-section of the Geoelectric tomography must performed by multiple spacing gradient arrays, with maximal spacing up to AB = 360 m, which

provided a survey depth of 50 to 70 m. Profiling is necessary to perform in several depth of investigations, according to the required depth investigation for each object.

Alongside in the downstream area of raw materials, self-potential surveys are necessary to carry out, in order to study the water filtering process through it.

3. HISTORIC CASES: DISCUSSION OF THE RESULTS

The seismic and geoelectric tomography results presented in this lecture was carried out for dam investigation of Fierza, Komani, Ulza and Vau Dejes Hydroelectric Power Plants (Frashëri A. 2004, Frashëri A. et al. 1998): Fierza Hydroelectric Power Plant (constructed in 1978) has an installed power 500 MW, Komani (1985) 600 MW, Vau Dejes (1971) 250 MW, and Ulza (1957) 25.6 MW (Hyrdroenergetics, 1999). In-situ geophysical investigations were carried out in order to resolve a wide specter of duties in these objects.

3.1. Investigation of dam structure and evaluation of the concrete physical-

mechanical properties

3.1.1. Diga e Hidrocentralit të Fierzës

The Fierza dam has a length in couple of 400 m and height of 187 m. The dam is constructed by raw materials (stones, gravel, filters and clay core). Seismic investigation of this dam is located in the concrete bottom of inspection and cementing gallery (Photo 1). In fig. 1 is presented the seismic surveys system. Fig. 2 shows the seismic investigation results. Concrete bottom of the gallery is characterized by very height velocity from 6.000 m/sec up to 10.000 m/sec for longitudinal waves P and 3.000 up to 6.000 m/sec of transverse waves. The same limit of the seismic wave's velocity varies also in cemented bed rocks- granites. Based on these data have been calculated physical-mechanic properties of the concrete and rocks (Table 1).



Photo 1. View of the Fierza Hydroelectric Power Plant dam.



Fig. 1. Seismic surveys system in Fierza Hydroelectric Power Plant dam.



Fig. 2. Results of the seismic investigation in Fieza Hydroelectric Power Plant dam.

Physical-mechanical properties of the concrete and cemented granites in the basement of the Fierza dam, according to the in-situ seismic investigation

Tab. No. 1

Layers			Vp	Vs	ρ,	Poiss. Coeff.	Dynamic mod	elasticity lulus,	RigidityMod.	Bulk Modul.	Volume compre-
Object	No	Н	m/s	m/s	g/cm ³	ν	in 10 ⁵ KG/cm ²		G, K, in in	K, in	ssion σ_c ,
		m.					After Vp	After Vs	x 10 KG/cm	KG/cm ²	$x10^5$ KG/cm ²
Beam	1	3.5	10000	3000	2.5	0.45	6.65	6.65	2.29	22.47	22.47
	1/a	1.5	10000	6000	2.5	0.22	22.36	22.36	9.17	13.30	13.30
	1/b	3.0	6100	3600	2.4	0.23	7.82	7.82	3.17	4.87	4.87
Cemen	2	9.5	10000	6000	2.6	0.22	22.36	23.25	9.17	13.30	13.30
-ted granite	3		6000	3000	2.4	0.33	5.87	5.87	2.20	5.87	5.87

From these data results that the concrete beam in the bottom of the inspection and cementing gallery have very good physic-mechanical properties of quality. The same quality has the cemented bed-rocks-granites of grout curtain.

3.1.2. Komani Hydroelectric Power Plant Dam

Komani dam has a length in couple 240 m and height 115 m. The dam presents a stone construction with a reinforced concrete screen. Seismic investigation is located in the concrete bottom of inspection and cementing gallery (Photo 2). Fig. 3 presents the seismic investigation results.



Photo 2. View of the Komani Hydroelectric Power Plant dam.



Fig. 3. Results of the seismic investigation in Komani Hydroelectric Power Plant dam.

According to the seismic investigation data results that concrete beam in the bottom of cementing gallery is characterized by height velocities of longitudinal waves P and transverse S, which respectively varies from 3400 to 6300 m/sec and 1800 to 2200 m/sec (Fig. 3). In Tab. 2 are presented the physic-mechanical properties values, according to the seismic data. In fig. 3 can see that the cemented riverbed gravel of grout curtain is characterized by height seismic waves velocities, 4200 m/sec and 2500 m/sec, respectively for longitudinal and transversal waves.

According to the electrical sounding near of the dam couple, results that raw material dam is constructed by some layers with different physic-mechanical properties, depended from the lithology of the raw material.

Physical-mechanical properties of the concrete and cemented granites in the basement of the Komani dam, according to the in-situ seismic investigation

Tab. No. 2

Object	Vp,	Vs,	Poiss. Coeffi-	Dynamic elestic modulus, $x10^5 kG/cm^2$		Volume Compre- ssion,	Concre -te	Concre- te
	m/s	111/8	Clefft	Vn	Vs	$\frac{0_{c}}{x10^{5}}$	status	Mark
				۰p	• 5	KG/cm ²		
Con-crete beam in the cemen- ting gallery	6300	1800	0.456	1.44	2.01	7.58	Good	M.250
	3400	2200	0.140	2.15	2.45	1.13	Good	M.150
Cemen- ted river bed gravel	4200	2500	0.226	2.78	3.40	2.07	Good	M.250

From these data results that the concrete beam in the bottom of the cementing gallery have physic-mechanical properties of good of concrete quality, with cement marking M250. The same quality has the cemented grout curtain.

3.1.3. Vaut të Dejës Hydroelectric Power Plant Qyrsaqi Dam (concrete part)

Two sections compose Qyrsaqi dam in Vau Dejes: Concrete section and gravel fill with central clay core section. The dam has a length in couple of 480 meters and maximum height of 79 meters.

Seismic profiling has been located in the concrete bottom of the galleries of different levels, 40 m and 30 m (Fig. 4, 5 and 6). Seismic tomography was performed between gallery of level 40 m and surface of the dam couple, and between galleries at 30 m and 40 m levels (Fig. 7).

Tomography data at different levels in the concrete section of the Qyrsaqi dam showed that, generally, the concrete has a characteristic wave velocities of greater than Vp=4000 m/sec and Vs=1900 m/sec (Tab. 3). At the left dam edge, an area where the Vp decreases to less than 4000 m/sec exists. The fact that, together with the P-waves velocities, the S-waves velocity decreases, shows that in this sector, the concrete has weaker physical and mechanical properties.

It is not enough to use only the seismic tomography among different galleries, because this leads to deficiencies in results and incorrectness in details. These results were compared with the supplementary seismic profiling on the concrete structure, especially in superficial spots. The concrete bottom of inspection galleries is necessary to investigate, to determinate the sectors of the galleries, which mechanically is weak. The mechanically weak concrete layer shows that the concrete will deteriorate under the water's effect, or the cementing in these sectors was made by poor quality concrete.



Photo 3. View of the Vau Dejes Hydroelectric Power Plant dam.



Fig. 4. Concrete properties at the depth 2 m of the bottom gallery, according to the seismic data, concrete part of the Vau Dejes dam.



Fig. 5. Concrete properties at the depth 0,5 m of the bottom gallery, according to the seismic data, concrete part of the Vau Dejes dam.

Seismic waves velocities in the concrete part of the Qyrsaqi dam in Vau Dejes Hydropower Plant

						Tab. 3	
Velocity	Blow i	n St. 0	Blow in 8.	5 meters	metrin in 17 meters		
values	Vp, m/s	Vs, m/s	Vp, m/s	Vs, m/s	Vp, m/s	Vs, m/s	
Minimal	3893	1845	3106	1696	2310	1498	
Maximal	4360	2117	3774	1988	2596	1731	
Average	4080	1960	3480	1820	2440	1610	

According to these seismic data have been calculated the values of the physicmechanical properties of the concrete of this dam (Tab. 4):

									Tab. 4
					Dyn	Dynamic		Bulk	Volume
					elasticity modulus, x10 ⁵ KG/cm ²		mudu-	modu-	compre
				Poi-			lus	lus	-ssion
Object	Vp	Vs	ρ,	sson			G,	К,	σ _c ,
	m/s	m/s	g/cm ³	Coeffi-	After	After	in	in	in
				cient	Ve	Va	x10 ⁵	$x10^{5}$	$x10^{5}$
				ν	٧p	vs	KG/cm ²	KG/cm ²	KG/cm ²
Gallery	1000	650	2.16	0.134	0.21	0.21	0.9	0.96	0.96
bottom									
Sottom	5800	2000	2.50	0.433	2.29	2.29	1.02	7.21	7.21
	1	1		1			1		

Physical-mechanical properties of the concrete in the Qyrsaqi dam in Vau Dejes Hydropewer Plant, according to the in-situ seismic investigation



Fig. 6. Seismic surveys results in the concrete part of the Qyrsaqi dam in Vau Dejes Hydroelectric Power Plant



Fig. 7. Seismic tomography results in the concrete part of the Qyrsaqi dam in Vau dejes Hydroelectric Power Plant

3.1.4. Ulza Hydroelectric Power Plant Dam

Ulza concrete dam of gravity kind has a length in couple of 340 meters and maximum height of 64 meters (Photo 4). Figs. 8, and 9 present the seismic investigation results. In Tab. 5 are presented seismic waves velocities and in Tab. 6 physical mechanical properties of the concrete. In the Ulza Dam, results from the seismic tomography survey indicates that the concrete in general is also characterized by high velocities of the seismic waves propagation Vp= 4300-5035 m/sec and Vs= 2412-2429 m/sec. The elasticity dynamic modulus is $(3.27-3.60) \times 10^5$ kG/cm². According to the tomography data, it is noticed that at the upper levels of dam, the longitudinal wave velocities Vp are, on average, higher than the lower levels. At the same time, at both levels, the transversal wave velocities are equal. In addition to that, the average square deviation of transversal wave velocity is almost twice less than the longitudinal wave deviation. These facts are an argument that the decrease in velocity and high fluctuations in velocities impacts on water penetration into the concrete pores. The velocities (Vp) in the lowest levels are lower than in the upper levels, as a result of being under constant high water pressure. The concrete of lower levels also contains more water. The mechanical properties of this concrete are also weaker than the upper levels. Considering the concrete mark 250 for lower levels (Dzievanski J. et al., 1981), based on the calculated physical-mechanical properties, the upper levels have concrete of higher value than 250, because the elasticity dynamic modulus is $3.96 \times 10^5 \text{ kG/cm}^2$. In the tomogram it is possible to define a sector, which characterized with physical-mechanical properties lower than the surrounding environment. Within this sector, the main water filtering of the gallery of lower level is observed (Photo 5).

Even at the dam of Ulza the inner walls of the inspection gallery, as well as in dam surface, have a low elasticity dynamic module, up to 74.000 kG/cm^2 . At this sector, several filtration of Lake Water are evidenced in the inner of dam. This state of concrete at the Ulza dam shows once more the impact of "ageing" phenomena on concrete



Photo 4. View of the Ulza Hydroelectric Power Plant dam.



Fig. 8. Seismic surveys results in dam of Ulza Hydroelectric Power Plant



Fig. 9. Seismic tomography results in dam of Ulza Hydroelectric Power Plant



Photo 5. Water filtrate in the inspecting gallery of dam, Ulza Hydroelectric Power Plant

Seismic vawes velocities in the concrete part of the dam in Ulza Hydropower Plant Table 5

		Vp, in	m/sec		Vs, in m/sec			
Tomography zones	min	max	aver.	Mean quad- ratic devia- tion	min	max	aver.	Mean quad- ratic devia- tion
Between dam couple and drossels gallery	3620	6240	5035	520	2120	2715	2429	196
Between drossels gallery and second gallery	3390	5030	4300	830	2160	2720	2412	170
Left dam edge	3850	6290	4940	851	2280	3770	2600	260
Right dam edge	2280	4270	3150	650	1880	2780	2440	300

Physical-mechanical properties of the concrete in the dam of Ulza Hydropewer Plant, according to the in-situ seismic investigation

Tab. 6

					Dyna	amic	Rigidity	Bulk	Volume
					elast	icity	modul.,	Modul.	compre
				Poi-	modı	ılus,	G,	К,	ssion
Object	Vp	Vs	ρ,	sson	x10 ⁵ K0	G/cm ²	in	in	σ _c ,
	m/s	M/s	g/cm ³	Coeff	After	After	$x10^{5}$	$x10^{5}$	in
					Vp	Vs	KG/cm ²	KG/cm ²	$x10^{5}$
				ν	-				KG/cm ²
Bottom	2 500	1100	2.40	0.380	0.82	0.82	0.30	1.13	1.13
of mid									
gallery	1200	230	2.14	0.481	0.3	0.03	0.01	0.29	0.29
Tomogr.	5035	2429	2.44	0.35	3.96	4.47	1.47	4.35	4.35
Dam									
couple-									
drossels									
gallery									
Tomogr.	4300	2412	2.44	0.27	3.68	3.67	1.45	2.67	2.67
drossels									
gallery									
Second -									
gallery									

3.2. Investigation of raw material dam and the evaluation of the soil and rocks physical-mechanical properties

Physical-mechanical state of rocks and soil was object to evaluations made in many objects and regions. In these cases we have used the seismic and geoelectric tomography. There are presented results of in-situ geophysical investigation in raw material part of Qyrsaqi and Ragami dams, in Vau i Dejes Hydroelectric Power Plant.

3.2.1. Qyrsaqi dam

The soil dam in Qyrsaqi is studied on clay core and at its slope. In fig. 10 and 11 are shown the geophysical-engineering- geotechnical sections of these dams.



Fig. 10. Electrical sounding results in the raw material part of Qyrsaqi dam, Vau Dejes Hydroelectric Power Plant



Fig. 11. Electrical and seismic tomography in the raw material part of Qyrsaqi dam, Vau Dejes Hydroelectric Power Plant

The clay material has a lower resistivity at the center and western edge of Qyrsaqi dam than the eastern edge. The seismic wave velocity is lower in this sector, too. The water filtering into the clay's core explains this. The average electric resistivity of the dam's core is about 100 Ohmm. However, in 5 sectors of the dam's core, this resistivity decreases up to 25 Ohmm in spots. It is evident that three of these anomalies coincide horizontally. The seismic tomography section shows that, beneath the superficial layer at the top of the dam, which has a thickness of 2-10 m and low velocities of seismic waves, (respectively Vp=1080 m/sec and Vs=550 m/sec), there is a second clay layer. This layer of clay has a thickness of 4 - 21 m, increasing in thickness towards the west, where the ground dam meets the concrete part of the dam. The velocities of seismic waves are lower in western dam sector. The clay's core, under the second layer by higher seismic waves velocities is characterized (up to Vp=2200 m/sec and Vs=800 m/sec). The elasticity dynamic module, calculated according to Vs data, varies from $(0.04-0.88)*10^{\circ}$ kG/cm^2 for the second clay core. Based on the geophysical investigation results, shown above, the areas with a lower electric resistivity and lower velocities of seismic waves than the other part of the dam's core are interpreted to be due to water filtering through the clay core. This interpretation does not exclude the possibility of heterogeneity of the clay's material during dam's construction .The increase of velocities of the seismic waves

toward depth shows than the clay's core is compacted. The configuration of seismic wave's velocity contours in the section shows normal bedding of core's material, with western dip. The study of these dangerous phenomena brings the necessity of monitoring the dam through geophysical methods, along with all other installed equipment from the Geologic-Technical Service of Hydropower Plant. Some periodic investigation over many years are necessary in order to observed the changes in time of electric resistivity and the seismic waves velocities.

Tab. 7 presents the physical-mechanical properties of the raw material of Qyrsaqi dam according to the seismic data.

Physical-mechanical properties of the raw material part of the Qyrsaqi dam, Vau Dejes Hydroelectric Power Plant, according to the in-situ seismic investigation

La	yer				Poi-	Dynamic		Rigidity	Bulk	Volume
		Vp	Vs	ρ,	sson	elasticity		modulus,	Modu.	compre-
No	Н	m/s	m/s	g/cm ³	Coef.	mod	ulus,	G,		ssion
	in					x10 ⁵		in	К,	Sh,
	m.				ν	KG	/cm ²	$x10^5$	in	in
						After	After	KG/cm ²	x10 ⁵	x10 ⁵
						Vp	Vs		KG/cm ²	KG/cm ²
1	5	840	300	1.70	0.43	0.04	0.04	0.02	0.10	0.10
2	15	1480	480	1.88	0.44	0.13	0.13	0.04	0.36	0.36
3		2400	1200	2.26	0.33	0.88	0.88	0.33	0.88	0.88

Tab. 7

Ragami dam.

Raw materials with clay core, Ragami dam in Vau Dejes lakeshore has a height of 29 m. As it results from the geophysical- geotechnical section analysis of fig. 12, the soil Ragami dam it is built by heterogeneous material by poor physical-mechanical properties (Photo 6). This lead to filtered the water through the dam. This filtering water flows are well fixed by self-potential anomalies in the downstream area of the dam.



Fig. 12. Eletcric resistivity tomography in the Ragami raw material dam in the lakeshore of Vau Dejes.





Photo 6. Downstream view of the Ragami dam, and filtration sectors

4. CONCLUSIONS

- Geophysical data on the stability of the constructive materials and rocks create the possibilities to apply the modern dynamic methods for re-estimation of the dam's stability and their monitoring.
- Geophysical methods represent an important part of the integrated and multi disciplinary modern complex methods for dam's investigation and monitoring. This is important because their information are put in the basement of modern design methods for construction works using. These methods are based on dynamic properties of the soil and rocks, where established construction object, as well to reconsider the sustainability of the capital facilities build many years ago, for the current state of their conditions, and to be more qualitative risk assessment and security.
- Today, in-situ geophysical controls have taken the great importance, because are unique methods for provide the data on the in situ situation of building materials, as found in nature.
- During in situ testing using geophysical engineering methods, the physic- mechanical properties of construction materials evaluated for an large volume and are more representative, and consequently become more accurate and most reliable the estimations.
- Of course, this does not mean that are not required laboratory tests. They are necessary only in that amount, as long as needed to determine the dependencies between physical and mechanical properties of building materials and soil.

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