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Monitoring special constructions behaviour, using topographical modern methods

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Abstract: Whether by human activity such as mining or by natural processes such as erosion, the world in which we live is continually changing. Buildings and dams settle, bridges flex and vibrate, rock masses shift, mud slides, glaciers flow and volcanoes erupt.

Environmental protection, as a relationship of mankind with nature, has evolved in time, as on the awareness of the entropic activities, with irreversible effects and with dramatic consequences on the modified natural environment.

Whether you monitor the movement of a volcanic slope, the structure of a long bridge or track the settlement of a dam; whether you measure, analyze and manage the structures of natural or man-made objects: the monitoring systems provide you with the right solution for every application.

Advanced data processing algorithms, together with powerful event management systems ensure that maximum benefit is derived from the measurement information provided by the instruments.

Topographic and cadastral measurements have a special importance in the environmental protection research, especially for monitoring the effects of nature’s geometrical modifications.

Dam monitoring has special importance because through a proper monitoring can be prevented unwanted events, that can be transformed in real social, economical, ecological disasters and therewith partially the design, execution and even exploitation errors effects can be removed. The surveying measurements made at Petrimanu dam have the porpoise to determinate the vertical displacements of the marks, regarding environment protection, during Lotru - Ciunget HPP refurbishment.

Keywords: environment, monitoring, dam, surveying.

1. INTRODUCTION

Engineering companies and contractors are facing challenges never experienced before. They are being charged with - and being held liable for - the health of the structures they create and maintain. To surmount these challenges, engineers need to be able to measure structural movements to millimetre level accuracy. Accurate and timely information on the status of a structure is highly valuable to engineers. It enables them to compare the real-world behaviour of a structure against the design and theoretical models. When empowered by such data, engineers can effectively and cost efficiently measure and maintain the health of vital infrastructure.

The ability to detect and react to potential problems before they develop helps in the reduction of insurance costs and the prevention of catastrophic failures that may results in injury, death or significant financial loss. A structural monitoring system will help reduce both your current and long term maintenance cost associated with structural movement.

A structural monitoring system reduces risks, as data analysis can be used to aid the understanding of current and future implications of structural movements. Safety and structural integrity concerns can be minimized. Contractors can reduce their risk exposure before, during and after a construction project by continuously monitoring the project as it progresses through its lifecycle. Potential problems can be detected and rectified before a critical situation develops.

Commissioned in 1972, Lotru-Ciunget Hydropower Plant (HPP) is an outstanding Romanian hydropower project, considering both its installed capacity of 510 MW, the largest in a project located on an inland river of Romania, and the complexity of the scheme.

Situated underground, 140 m below the thalweg of the Latori□a River, Lotru-Ciunget HPP is equipped with three units of 170 MW each, with Pelton turbines and vertical, synchronous generators.

The technical characteristics of Lotru-Ciunget HPP ensure the following functions:

- peak load power plant, it covers the variable areas of the load curve;
- participation to power and frequency adjustment within the National Power System, being able to operate both under generator and synchronous compensator mode;
- emergency power plant; it can start operating at maximum capacity in 4-5 minutes;
- during high waters periods, it contributes to flash flood mitigation. These functions allow the plant to provide the services needed for the proper operation of the National Power System.

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The development scheme of Lotru - Ciunget HPP is based on a modern principle regarding inflows and falls concentration, and consists of two main categories:

• The main diversion, where the inflows are collected and where the 4 m3/sec discharge is captured. It consists of the following elements: Vidra dam, creating a multi-annual storage with a volume amounting to 340 million m3, water intake, a 13.7 km long headrace gallery, surge tank, butterfly valve house, a 1.32 km penstock gallery, spherical valves house, Ciunget underground power plant (510 MW), transformers hall, related cable gallery and tailrace.

• The Main Water intake network and secondary headrace – they collect the inflows both from the Lotru River basin and from the adjacent river basins. The collected inflows are gravitationally transported or pumped into Vidra reservoir, to provide the 809 meters head necessary for operation. This network consists of 83 water intakes, 4 concrete arch dams (Galbenu, Petrimanu, Balindru and Jidoaia) – three of them create pumped storages - and galleries amounting to 128.2 km (fig. 1).

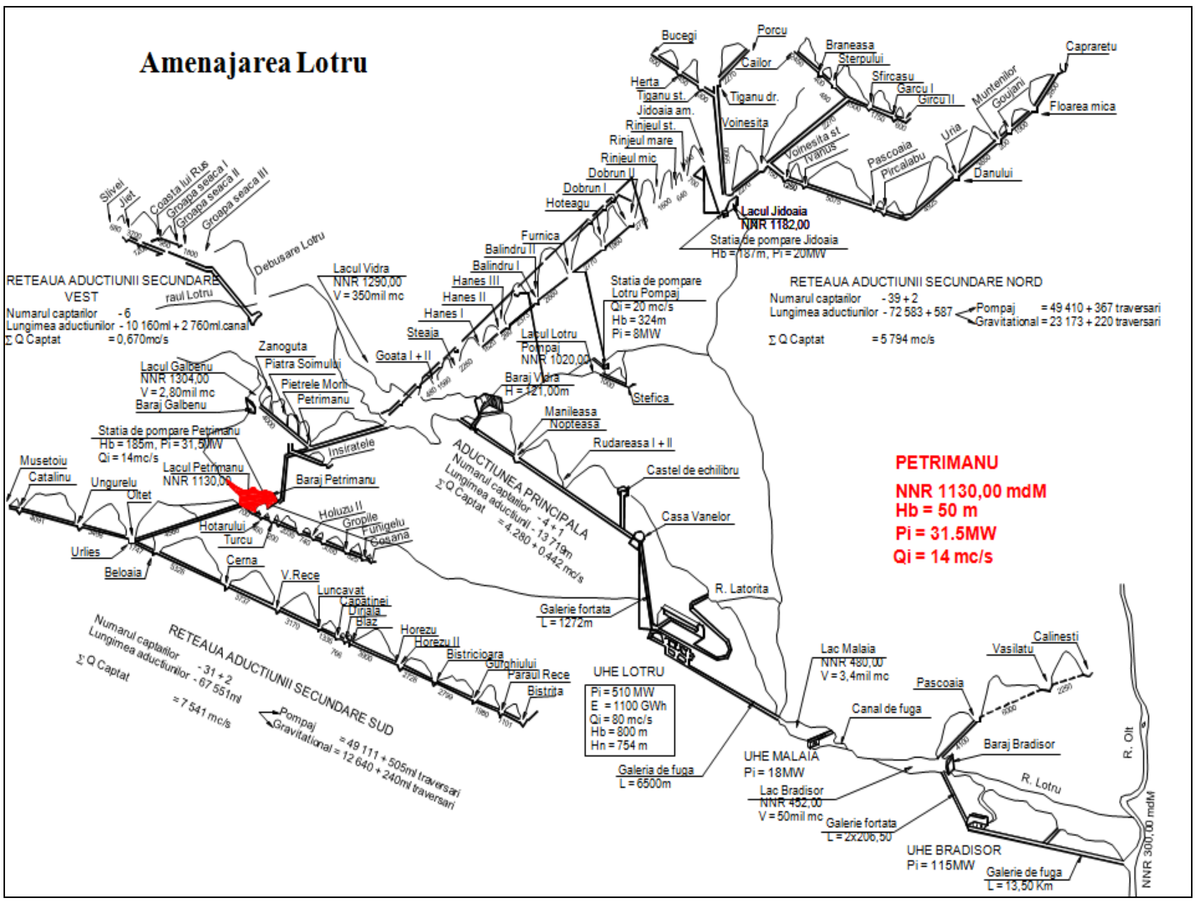

Fig. 1 Lotru Water intake

The storage Lake Petrimanu is made on the Latori□a River and gathers most of the waters caught in the southern headrace network (without those accumulated in the Lake Galbenu and caption În□iratele) from a 236 km2 surface. There are 28 captions; the gallery length is of 55,416 m, and the caught flow is 5.384 m^3/s. As a total the southern network has a number of 31 captions along the water course, the headrace length of 67.551 m out of which 745 m crossings and it catches a flow of a 7,514 m^3/s.

Fig. 2 Petrimanu dam overview

Petrimanu Dam and pumping station:

• Year of commissioning: 1977

• The concrete arch dam collects the inflows from the secondary catchments; the water is then pumped in Vidra reservoir.

• The power plant has 3 pumping units, equipped with MOS horizontal synchronous generators of 10.5 MW.

The Petrimanu dam is a concrete arch dam, 49 m high, a crown length of 190 m (crown level at 1,134 mdM), it embedded a concrete volume of 56.000 m^3 and it creates a 2,500 mil m^3 storage lake.

The pumping station Petrimanu directs the accumulated flow at a 185 m height, to a gallery from which it falls by gravity into the main storage Lake Vidra, gathering on its way the waters derived from Lake Galbenu and În□iratele caption.

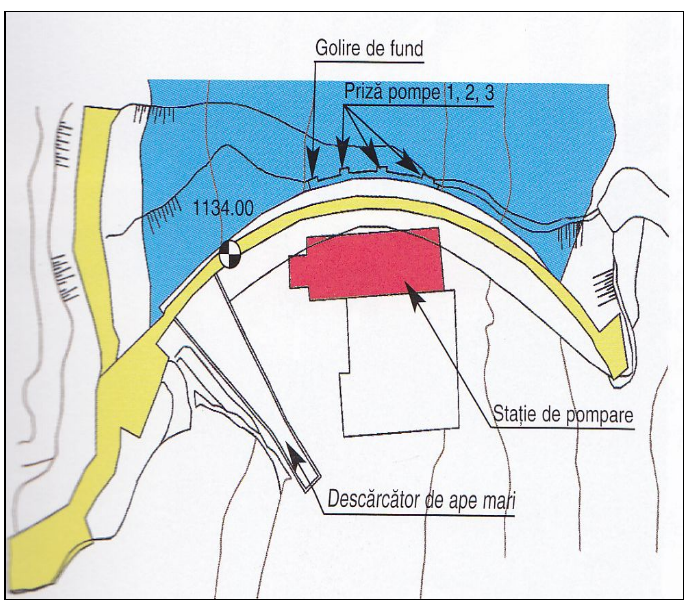

Fig. 3Petrimanu dam- Overview

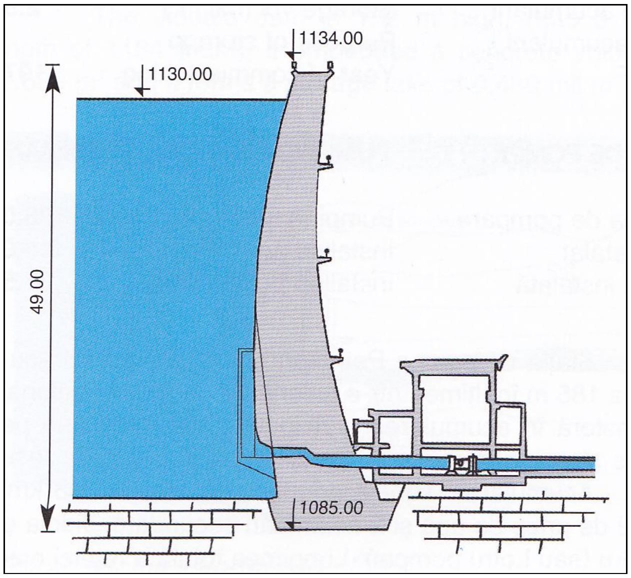

Fig. 4 Petrimanu dam- Cross section

2. RESULTS AND DISCUSSIONS

Considering the refurbishment of Lotru - Ciunget hydropower plant, monitoring the hydro technical constructions is very important. During the refurbishment, the water dam was emptied and the forces that acting on it, are very unusual.

The surveying measurements made at Petrimanu dam have the purpose to determinate the vertical displacements of the landmarks.

For determining the vertical displacements we used four measuring cycles: the "zero" measurement (05.10.1976), the first measuring cycle (01.08.2009), the second measuring cycle (01.08.2010) and the third measuring cycle (04.10.2011).

The "zero" measurement was provided by the beneficiary. The following measuring cycles were part of our research. The first measuring cycle was made during special circumstances because the storage lake was emptied. During the second measuring cycle the storage lake was refilling and during the third measuring cycle the storage lake was completely filled. The atmospheric conditions, during the measurement cycles, were good (there were no rainfalls, the environment temperature varied between 12^0C and 15^0C), providing good working conditions.

The process for determining the vertical displacements contains the following steps:

1. levelling measurement performing
2. measurement processing
3. results interpretation

The displacements were obtained as difference between the horizontal coordinates and heights, from "zero" measurement, and the same elements determined in the current measurement cycle.

For obtaining the water dam vertical displacements we performed topographical measurements in the levelling network (figure 7). The levelling network is composed from twelve height marks fitted to the crown of the water dam (figure 6) and three stationary height marks situated outside the water dam influence zone (figure 5).

Fig. 5 Stationary height mark at Petrimanu dam

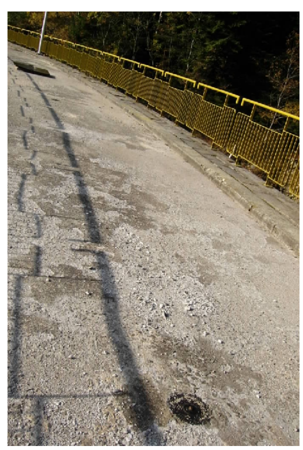

Fig. 6 Height marks on the crown of Petrimanu dam

The measurements performed in the levelling network were made with a levelling instrument of type Leica DNA 03, which ensures a measuring precision of 0.3 mm / 1 double levelling kilometre. The staff readings were made on a levelling staff with bar code.

For measurement setting off it was used the ends supported traverse or the loop traverse method, depending on the terrain existing conditions.

The measurements were processed on the computer with APORT 2000 software.

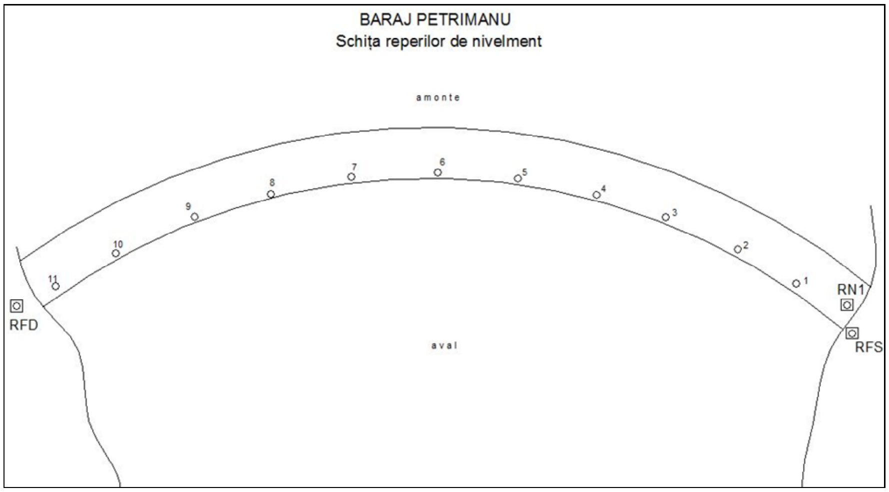

Fig. 7 Petrimanu dam- The levelling network

The displacements are obtained from the difference between heights determined on the initial measurement and various measurement cycles.

After processing the measurements the results are presented in the following, both in tabular (table 1) graphical form (figure 8).

THE HEIGHT MARKS DISPLACEMENTS Table 1

Vertical landmark No.	Differences from the ”zero” measurement (mm)				
	Measuring cycle	Measuring cycle	Measuring cycle	Measuring cycle	Obs.
	May. 1980	Sept. 2009	Sept. 2010	Oct.2011	
RN1					stationary
RFD					stationary
RFS					stationary
R1	0.00	3.08	3.40	3.93	
R2	0.00	3.52	3.39	3.34	
R3	0.00	4.59	4.73	5.38	
R4	0.00	4.39	4.43	4.67	
R5	0.00	5.25	5.47	6.13	
R6	0.00	3.65	4.09	4.9	
R7	0.00	4.08	4.44	6.16	
R8	0.00	2.41	3.20	4.47	
R9	0.00	0.95	1.93	3.3	
R10	0.00	0.89	1.80	3.30	
R11	0.00	-0.38	0.44	1.91	
R12					inactive

In figure 8 are presented the displacements of the height marks from Petrimanu dam, from different surveying cycles.

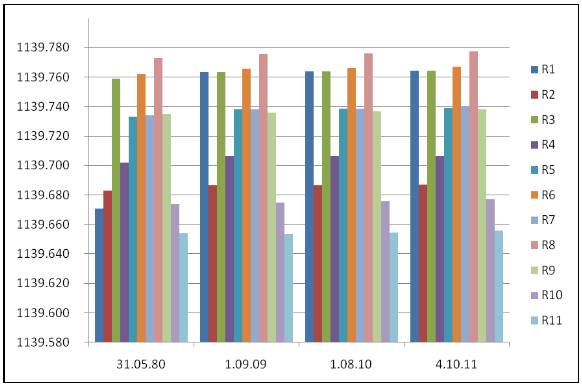

Fig. 8 The displacements evolution of height marks

- Analyzing the measurements, we can observe that the height mark number 7 has the biggest vertical displacement 6,16 mm, in year 2011. This fact can be explained because the height mark is situated near the water dam abutment from the left bank.

Other important conclusions from these measurements are:

- Analyzing the events that produced these vertical displacements (in year 2009 the Lake Petrimanu was emptied along with Lake Galbenu and Lake Vidra because of the HPP Lotru - Ciunget refurbishment measures, and in year 2010-2011 these three lakes were refilled again) we can assert that these vertical displacements are normal, so non hazardous.
- Although these vertical displacements are nonhazardous they must be permanently monitored for observing in time the effects of the water dam emptying phase and on this way preventing possible catastrophes.

3. PERSPECTIVES

For future strategy, as a personal proposal, we suggest this project continuation through sensors and reference stations for monitoring (GNSS) positioning, also the periodic 3D monitoring by laser scanning the dam strategic areas (Fig. 9).

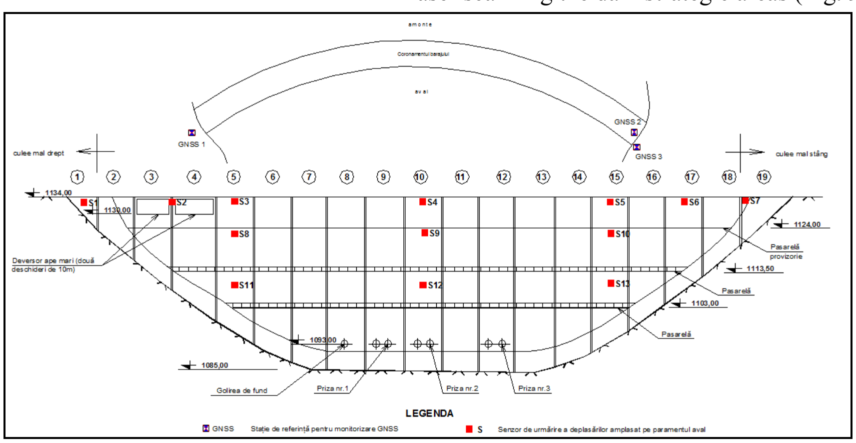

Fig. 9 Future strategy proposal

4. CONCLUSIONS

Monitoring this kind of constructions is made both with physical methods and topographic methods. The advantage of physical methods is that through the used gear they are providing information about the monitored construction behaviour at small time intervals (hours, days, weeks). This information has a relative character because the measurements are made on certain construction elements reported to other construction elements. The topographic methods have an absolute character because the measurements are executed towards the construction independent reference system.

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