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Geodetic studies on hydrotehnical structures movements and deformations monitoring

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Abstract: The advantage of a real prognosis determination is the fact that, in time, the investments can be made in good timing and with maximum efficiency; beside that, their systematic monitoring is of scientific and practical importance.
Monitoring and controlling industrial and hydropower condition involves a system configuring by acquiring geometrical and mechanical parameters, a database creation, analysis and prediction.
The developing of these monitoring systems leads to automated procedures implementation, for structural defects referral and diagnosis, construction inspections disposal ensuring human operator subjectivity, record keeping for long time periods, and benchmarking defects arising.
Currently, behaviour monitoring during construction phase exceeded the narrow routine maintenance and acquired a scientific nature, aimed at studying and verifying proper operations of solutions that fully satisfy the requirements imposed by national economy development.
Based on these considerations, the research highlighted in this paper is based on the contribution of topographic measurements and modern surveying technologies while monitoring "Poiana Mărului" dam's (from Romania) behaviour.
Keywords: monitoring, construction, benchmark, environment, movement, deformation.

1. INTRODUCTION

Engineering structures (such as dams, bridges, high rise buildings etc.) are subject to deformation due to factors such as ground water level changes, tidal phenomena, tectonic phenomena etc. When it comes to savings and improvements in safety both during and after the execution of constructions, the cost is very important. As a result, a matter of considerable practical importance is the design, execution and analysis of surveys. Deformation refers to the changes of a deformable body (natural or man-made objects) which undergoes in its shapes, dimension and position. Therefore it is important to measure these movements for the purpose of safety assessment and as well as preventing any disaster in the future. [1]

The measuring techniques development has permitted and created the possibility to observe and emphasize the behaviour of the studied buildings. So, there are a significant number of classification criteria, methods of research and observation of buildings and structures.

By the place where equipment is located during the observations process there are two possibilities to determine the movements and deformations:

- **Physical methods**: when the equipment is located inside the building – in this case the equipment moves at the same time with the building, the relative movements and deformations being evaluated.
- **Geometric methods**: in this case, the equipment is placed outside the building or outside of its deformation area – in this case the measurements will be linked to a network of fixed points situated outside the deformation area and factors that can affect the building or the foundation ground on which is situated. [2]

Statistical studies have shown that the average destruction risk of a hydrotecnical construction (dam) is about 0.5%, and the shutdown risk for an extended period, as a result of accidents, is about 2% - 3%.

Analysing the recorded dams' destructions, it is clear that the vast majority are due to the flippancy with which they were designed, built and operated. An important part, common to all dams, is the first measurement which has a very strict control in all phases of design, construction and operation.

During exploitation, dams and lakes should be closely monitored. Dam breaks are accidents which do not occur suddenly, but almost always there are preliminary danger indicators which would allow limit or even avoid disasters by taking measures.

The dam breaking analysis shows that the destruction percentage risk is much higher in low height dams than the other dam types. The explanation is that big dams adopt a higher safety factor.

Safety coefficients must be enacted according to the dam size but, on the consequences of breaking, are given the following directions:

- a possible rupture (deformation and seepage monitoring) would occur downstream, according to the dams importance;

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- treating problems from geotechnical point of view helps to establish the operating conditions given in the main consequences of a dam failure;
- treating dam stability and resistance differently depends of the breaking consequences.

A behaviour constant surveillance is required in order to reduce risk factors and to avoid destructive effects of dams and other outbuildings (penstocks, canals etc.) destructions. Visual observations are made during the entire construction phase and also on the phenomena which affect the construction stability.

Rock dams' visual observations are mostly related to seepage and slides. Concrete dams' visual observations are especially related to cracks and plots relative displacements.

For the dam submerged areas recourse to divers equipped with video cameras, anomalies are detected by visual examinations; they are photographed repeatedly at certain time intervals depending on the benchmarks evolution tracking.

Dam works, as well as foundations and slopes, show permanent deformation under the influence of water pressure and heating from the sun. The deformations can occur daily and seasonal, they are related to the lake filling and emptying.

The dams' body suffers movements induced by the water accumulation, by tectonic movements and other factors. To follow up is recommended that the reference system – for microtriangulation - the benchmarks to be mounted outside of the influence area of the dam, which is correlated with benchmarks, mounted on the dams' body. Measurements are made with a higher frequency in the first period of accumulation operation and subsequent periodic checks are made; if deviations from normal movement appear, they are compared with the limits set by the construction engineer, to make their analysis and interpretation [3].

Hydraulic constructions behaviour monitoring in time is based on the evolving nature of the track parameters. These parameters are based on the early value (when the works are commissioned) and stabilizes at certain values allowed by standards, these values evolving periodically.

Through this process the absolute values of horizontal or vertical movements will be established. The topographic-geodetic methods belong to this category of movements and deformations determination.

Many studies have been undertaken in Romania on this topic, even patents were assigned regarding the technology for diagnosing the stability of hydrotechnical dams. An eloquent example is patent number RO126246-A2 according to which, the monitoring method is destined to determine the vertical and horizontal shifting of the monitored dam body, some fixed marks being mounted for this purpose in the dam body, and in the proximity thereof both downstream and upstream, there being placed other marks, said marks being provided with GPS receivers for determining the coordinates, the data gathered in a sufficiently long period of time being processed, and the values resulting in certain intervals being compared to one another thereby punctually determining the shifting of the dam at time intervals. [4]

2. "POIANA MĂRULUI" DAM MONITORING USING MODERN GEODETIC TECHNOLOGIES

In order to sustain our point of view, we are presenting in our paper, an eloquent example: "Poiana Mărului" dam from Romania.

In close proximity of "Baile Herculane" resort one can find "Cerna" Dam, forming a beautiful and spectacular lake. "Cerna Dam" is also known as "Jovan Valley". It is made of rock fill material, waterproofed with clay. This dam is on top 10 height dams from Romania. It is part of hydropower "Cerna-Balerca".

"Bistra – Poiana Mărului – Ruieni – Poiana Ruscă" hydroenergetical scheme dates back to the end of the VIIIth decade of the XXth century when the first geological prospection and designing schemes began. This scheme (Fig. 1) foresaw the arrangements for the waters belonging to the superior hydrographical basin of Timiş river. The whole scheme is situated in Caraş-Severin county, upstream from Caransebeş municipality and it compounds three distinct schemes.

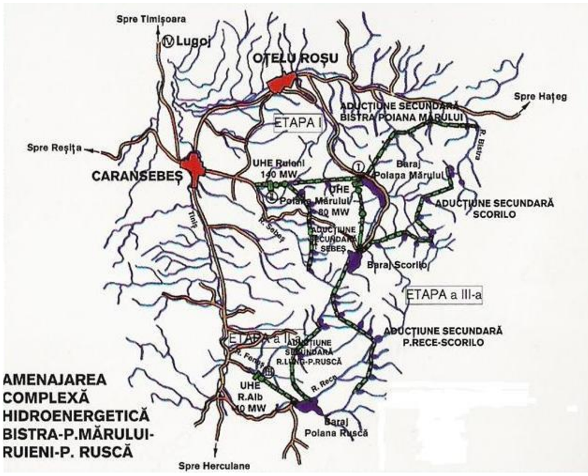


Figure 1. "Bistra – Poiana Mărului – Ruieni – Poiana Ruscă" hydroenergetical scheme

"Poiana Mărului" dam, built in 1991, is a rock fill dam with clay core, and has the following characteristics:

- 125.50m height;
- 407.00m crown length;
- 10.00m crown width;
- 487.00m maximum length at the basis;
- 625.00mdM crown height;
- 4.18mil.m^3 rock fill volume;
- 0.62mil.m^3 clay volume;
- 0.35mil.m3 filters volume.

The dam is brought to the final height and realizes a retention about 96.20 mil.m3 on a length of the lake of approximately 8km, having a normal level of retention NNR = 620.00mdM.

The location of the dam was practically imposed by the limited area of the gorge, being delimitated on the downstream by the river bend and the changing in orientation of the right slope, and on the upstream by the pronounced broadening of the valley. The gradient of the slopes have been relatively uniform, their values coming under 38". The presence of the metamorphic craggy rocks on the entire surface on the barrier basin together with the smooth slopes, covered in a not too thick diluvium, confers to the whole scheme good stability and an absolute impermeability.

Figure 2. Image of the “Bistra – Poiana Mărului – Ruieni – Poiana Ruscă” hydroenergetical scheme

Topo-geodetic measurements realized for “Poiana Mărului” dam aimed to determine both horizontal and vertical displacements for monitoring benchmarks mounted on the dam berm. The displacements result from the difference between coordinates, respectively for the settlements, the heights determined in the first measurement session and the same heights determined in different actual sessions.

Monitoring the behaviour in time of “Poiana Mărului” dam has started ever since 1991, during its execution. The levelling and the microtriangulation network created especially for this comprise in 39 fixed benchmarks, 6 microtriangulation pilasters and 6 fundamental height marks.

The topographic measurements for both the microtriangulation network and the levelling network have been realized between 14.06.2010 and 19.06.2010. During the measurements campaign, the water height of the lake varied between 615.35m and 616.35m (Fig. 3), the environment temperature oscillated from 11 to 25°C. The atmospheric conditions were generally good, ensuring optimal work conditions.

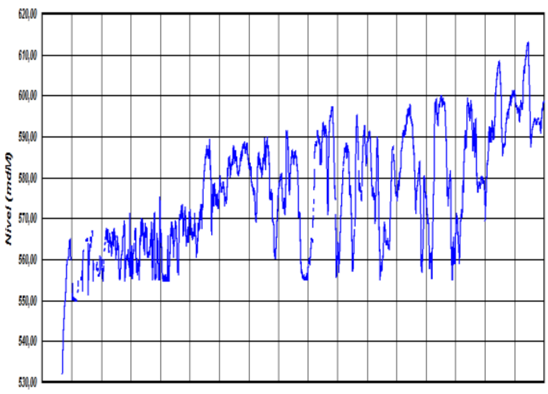
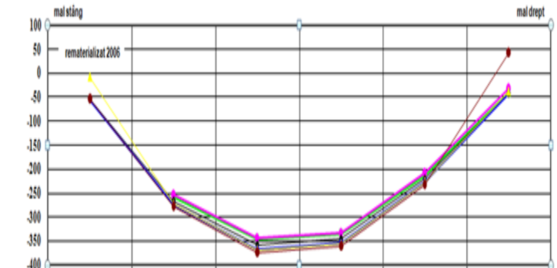


Figure 3. The water height of the lake between January 1995 and June 2010

3. ANALYSING DATA RESULTS

The measurements for the microtriangulation network have been realized using a Leica TCR 1201+ total station having an angular precision of 1cc, in good temperature and environment conditions. The installation of the instrument above the observation pillar was realized by forced centring with the aid of a special centring nutshell device. Sighting devices, painted in contrasting colours, white and red, have been placed on the benchmarks in order to facilitate their pointing. [3]

The accuracy for determining the settlements of the benchmarks belonging to the levelling network is 0.25mm and the maximum displacement was recorded at RN3-13, namely 5.9mm, relatively to the first measurement (Fig. 4).



	R21	R20	R19	R18	R17	R16
Nov.05		-256,85	-345,91	-334,01	-212,25	-38,19
Nov.06		-253,64	-344,38	-332,37	-208,47	-30,97
Nov.07	-52,70	-266,60	-358,70	-346,50	-220,60	-40,00
Oct.08	-54,40	-272,70	-366,70	-354,40	-226,00	-41,50
Nov.09	-7,60	-273,00	-369,00	-356,60	-226,40	-38,20
iun.10	-53,00	-277,90	-374,70	-361,60	-233,00	43,10

Figure 4. Example of diagram showing the evolution of the settlements of different benchmarks

The research conducted highlights the necessity of a modern approach based on generating different qualitative reports shaped as evaluated precision indices and the characteristic elements of the ellipse of errors for the benchmarks belonging to the tracking network.

In conclusion, analysing the bench mark tracking deflection values, and comparing them with the previous measuring cycle, both horizontally and vertically, we can say that they are relatively small and in ranges from normal for a rock fill dam. [5]

4. CONCLUSION

The application of modern topo-geodetic methods to study the behaviour of different types of constructions represents an essential condition in the real time evolution highlighting of a construction part or an entire structure as a whole.

The settlements, horizontal movements or inclinations of the tall buildings measurement, processing, calculation and representation can be done today with automated modern topo-geodetic technologies, which associated with the correct application of specific methods, gives the guarantee of a fair highlights of buildings phenomenon of instability.

With the help of the new geodetic methods and technologies with a high automation degree, the field of construction observation behaviour, submitted to different disturbance factors, becomes a branch of topographical engineering with applicability to various types of civil engineering, in close connection with the requirements of urban development and environmental protection.

A key objective of monitoring hydrotecnical constructions behaviour in time is to reduce risks, meaning not to achieve the limit state, which would involve either the ability to meet the operating conditions loss, or to generate hazards. Operating security loss is possible by making systematic observations and measurements on the parameters considered as response characteristics for a construction (such as structural deformations and displacements) to exterior factors.

Modern topo-geodetic studies application on different construction type behaviour is essential in highlighting a real time evolution of a construction element of or an entire structure as a whole.

ACKNOWLEDGEMENT

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