STABILITY MONITORING OF A ROCKFILL DAM

Alexandru Petru ALOMAN, MSc. Stud. Eng., „1 Decembrie 1918” University of Alba Iulia, Romania, alexandru.aloman.sicmi23@uab.ro
Silvia Alexandra DREGHICI, Lect. PhD. Eng., „1 Decembrie 1918” University of Alba Iulia, Romania, apopa@uab.ro

***Abstract**: Large dams, with their impressive structures, are included in categories of high importance constructions. Therefore, all the repeated systematic activities involving surveying, registration, processing and interpretation of certain parameters defining the way they maintain their requirements for stability and durability play an important role in stability monitoring. The paper focus on the knowledge of the building state and behavior during the considered period of time in relation to the initial prediction of the designer and to the previous monitoring period. The case study refers to the Oașa Dam, the main hydropower construction on the Sebeș River, Alba County. Also, it is important to establish and to highlight „atypical” phenomena which are able to produce degradations or changes in building safety and functionality. When such phenomena are reported during the monitoring of the building behavior, a commission of specialists will come up with proposals for possible measures in order to maintain, within acceptable limits, the building functionality, security and stability. In such cases, there is also required to improve the monitoring methods.*

***Keywords:** stability monitoring; rockfill dam; geodetic monitoring network; repeated geodetic measurements; building behavior; functionality; security and stability*

1. Introduction

Rockfill dams are large constructions, built of large size rock blocks and boulders. They are classified in the first and second class of importance. The case study in the present paper is the largest retention rockfill dam built along the Sebeș River, Oașa Dam Its main features are: maximum height 91m, crest altitude: 1259m (Black Sea Altitude System 1975), crest length 300m, crest width 10m, upstream slope 1:1,3, downstream slope 1:1,6, retained water volume 136mil.m3 [1].

The stability monitoring activity is developed and should take place for the entire life of the building, in order to obtain information regarding the building capacity of normal exploitation, security assessment for avoiding any incidents, accidents or damages, as well as obtaining information for improving building activity [1].

The main objectives of the stability monitoring of the dam are [2], [1], [3]:

- Ensuring the building safety and durability, by detecting dangerous phenomena in time and the area where they occur;
- Monitoring the evolution of predictable phenomena with possible negative effects on building exploitation;
- Operational identifying of reaching the warning criteria or the limit values, given by the measurement and control equipment;
- Efficiency verification of the applied intervention measures;
- Verification of the building impact on the environment;

- Assuring sufficient and reliable data for statistical processing, used for establishing the appropriate value ranges for normal and safe exploitation, considering the influence factors for the dam and the environment, during the entire building life cycle. These value ranges are required to assess the validity of the calculation assumptions and for setting the value ranges of “attention”, “warning” and “alarm” for certain parameters;
- Changes in the execution or intervention project, when the real state of the building does not correspond to the calculation assumptions;
- Assessing the behavior of new types of materials in real and complex conditions;
- Experimental verification of new processing methods.

2. Materials and Methods

Geodetic monitoring is carried out on the basis of a project including [2], [4]: the argumentation for establishing the geodetic monitoring, short description of the building (type, main features, dimensions etc.), geodetic monitoring objectives, phenomena, criteria and value limits, monitoring geodetic network, surveying methods and instruments, surveying plan correlated with the pre-use and exploitation phase, processing methods and data analysis, decision-making responsibilities, recommended measures in case of occurrence of events related to risk factors etc.

The stability monitoring program is primarily reflected by the surveying frequency (Table 1). It can be modified during the building exploitation phase, depending on the retention stage and its behavior [1], [5].

Table 1. Surveying frequency – measuring and control equipment, Oașa Dam

Monitoring parameters	**Measuring and Control Equipment**	**Surveying frequency**		
		Normal	**Exceptions**	**Automated**
Displacements	Object points – crest	1/year	Immediately after the event	-
	Object points – downstream slope	1/year		-
	Reference points	1/year		-

In normal behavior conditions, parameters values, determined by measurements, may vary within a normal variation range, characterized by minimum and maximum recorded values [1], [4].

When measured values tend towards the maximum limit of the normal variation range or even exceed the variation limit through a slow, fast or sudden evolution, these values can take on a wider meaning, from attention and warning values to alarm values and critical situations [1] [4].

For determining the parameters values, measuring and control equipment for building monitoring is used [1], [2]:

- Oașa Dam: hydrogeological boreholes and hydrometric devices for piezometric levels; drainage and spillway boreholes for infiltration and drained flow; dilatometric clamps for relative displacements; levelling benchmarks, vertical settling devices, horizontal level devices, horizontal devices with control points for absolute displacements; inclinometers for slope deformations;
- retention lake: topographic and bathymetric cross-sections for clogging evolution.

A geodetic monitoring network, containing reference geodetic points and object geodetic points, is used to assess the dam stability, allowing the determination of displacements and deformations. The location of the geodetic points must comply with certain rules imposed by specific instructions, namely [3], [6], [7]:

- the geodetic points are placed in stable places;
- geodetic points are not placed in the institution courtyard; though, some leveling benchmarks are placed in the outer foundation of the institution buildings;
- there are no geodetic points closer than 100m from high voltage networks, or 50m from communication lines;
- the points of the geodetic monitoring network are placed so that the horizontal directions do not pass too close to surfaces that increase lateral refraction.

Possible horizontal displacements and deformation are determined using microtriangulation measuring method (Fig. 1 and Fig. 2). The microtriangulation monitoring network can be divided into two parts [5]:

- upstream network, including 5 reference points (pillars PD5, PD6, PS6, PS8 and PS9) and 46 object points placed on the concrete slope, on five levels;
- downstream network, including 7 reference points (pillars PS, PS2, PS3, PS4, PS5, PD7 and PD8) and 36 object points placed on the downstream berms of the dam.

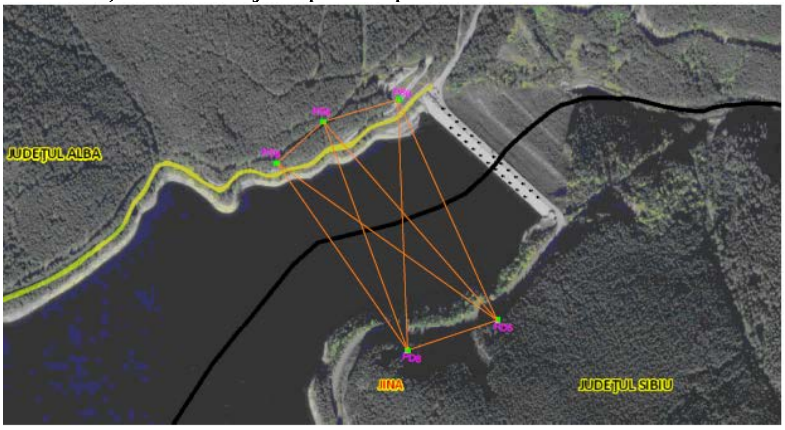

Fig. 1. Microtriangulation upstream monitoring network – reference points [5]

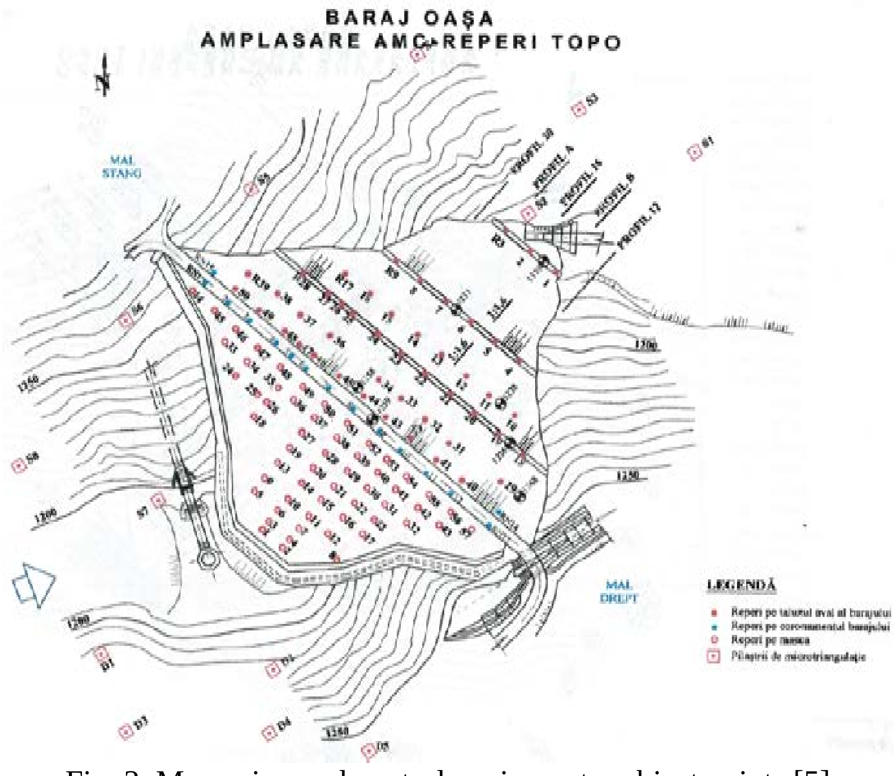

Fig. 2. Measuring and control equipment – object points [5]

The displacement and deformation analysis refer to rigorous measurements processing and results assessment by statistically comparing with a set of significand measurements with corresponding values obtained throughout the building’s existence. Thus, it is checked whether the variables that identify the building behavior, as well as the values related to the environmental and operational conditions are included in the range of previously obtained values and if they are consistent. Also, by statistical assessment, possible building evolution over time can be highlighted, separating reversible phenomena (referring to variations of the retention rate, the technical state of the building, the precipitation regime etc.) from irreversible ones (displacements and deformations) [1], [7].

The results of the repeated geodetic measurements are analyzed in correlation with the physical measurements carried out using measuring and control equipment.

3. Results and Discussion

For the displacement and deformation analysis, specialized computational and processing softwares were used to adjust repeated geodetic measurements in the geodetic monitoring network, for the considered measurement epochs related to the reference one. Some of the results are presented in the following summary tables of the coordinate differences (Table 2 and Table 3), as well as displacement diagrams (Fig. 3, Fig. 4) [1], [7].

Table 2. Horizontal displacements on X axis – reference points of the upstream monitoring network [1]

Oasa Dam – Horizontal displacements [**mm] – X axis**					
Pillar	**PS6**	**PS8**	**PS9**	**PD5**	**PD6**
ref	0,00	0,00	0,00	0,00	0,00
ian. 2012	7,06	0,00	-3,71	0,00	0,00
apr. 2013	7,09	0,00	-4,49	0,00	-2,81
nov. 2015	7,66	0,00	-4,74	0,00	-3,57
mai. 2017	8,09	0,00	-4,91	0,00	-3,29
aug. 2018	8,75	0,00	-4,98	0,00	-2,70

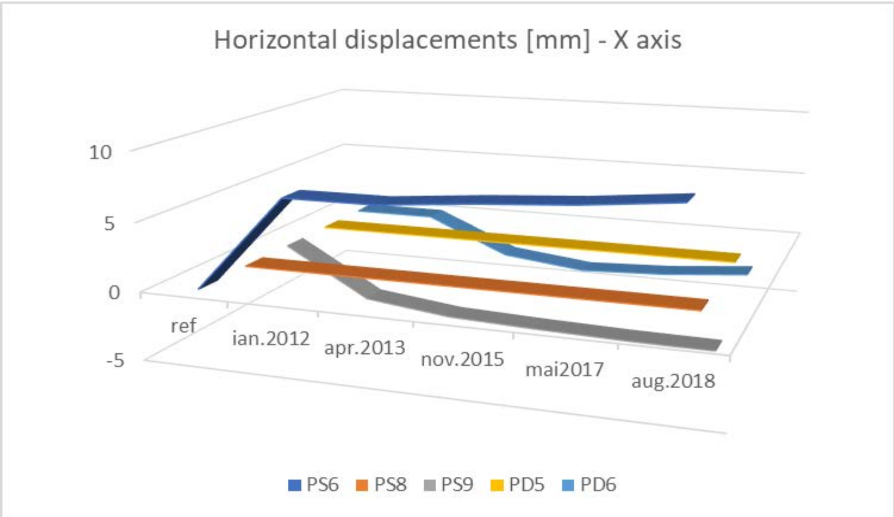

Fig. 3. Diagram of horizontal displacements – reference points of the upstream monitoring network

Table 3. Horizontal displacements on Y axis – reference points of the upstream monitoring network [1]

Oasa Dam – Horizontal displacements **[mm] – Y axis**					
Pillar	**PS6**	**PS8**	**PS9**	**PD5**	**PD6**
ref	0,00	0,00	0,00	0,00	0,00
ian. 2012	-6,05	0,00	-1,25	0,00	0,00
apr. 2013	-6,63	0,00	-0,89	0,00	-1,93
nov. 2015	-7,14	0,00	0,00	0,00	-2,74
mai. 2017	-7,81	0,00	-1,21	0,00	-2,90
aug. 2018	-7,73	0,00	-0,96	0,00	-3,60

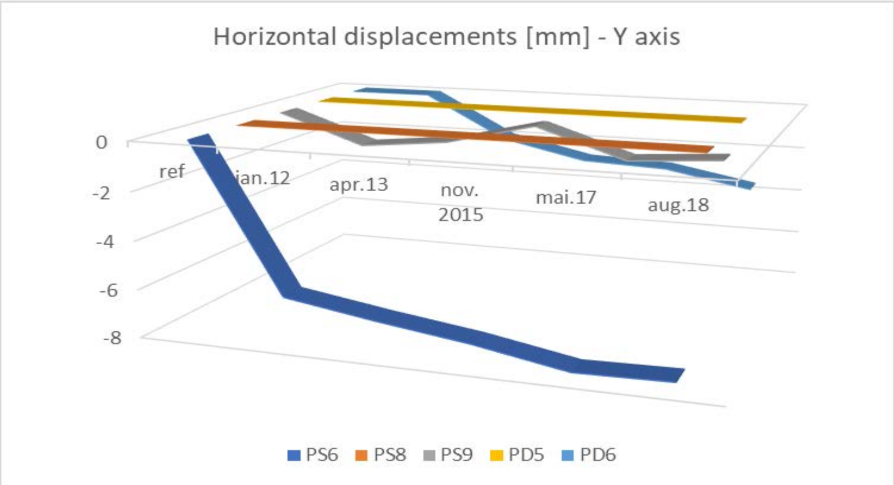

Fig. 4. Diagram of horizontal displacements – reference points of the upstream monitoring network

Analyzing the results, the following observations can be made [1]:

- the horizontal displacements of the reference points on X axis is included between -4,98mm and 8,75mm;
- the horizontal displacements of the reference points on Y axis is included between -7,81mm and -0,89mm;
- the maximum horizontal displacement on X axis, 8,75mm, is registered in Aug. 2018, in point PS6;
- the maximum horizontal displacement on Y axis, -7,81mm, is registered in May 2017, also in point PS6.

4. Conclusions

The geodetic measurements were made in difficult conditions due to poor visibility between the geodetic network points. In the downstream part of the monitoring network, there was no visibility between the pillars, nor was it possible to restore it. The grown vegetation downstream is a tree-like one and it cannot be deforested without notices and approvals from the competent institutions.

For the case study, the maximum displacement values and most relevant ones were identified for point PS6 of the upstream monitoring network.

A correct deformation analysis should involve not only processing repeated geodetic measurements and results statistical assessment, but a result statistical analysis in the context of physical, geological, geo-technical and environmental parameters [7], [4].

5. References

1. ****, Documentație de analiză a comportării construcțiilor din administrarea Hidroelectrica S.A., 2020*
2. ****, Normativ privind comportarea în timp a construcțiilor – Indicativ P130-1999*
3. *Palamariu, M., Popa, A., (2009): Urmărirea comportării terenurilor și construcțiilor, Seria Didactica, Universitatea “1 Decembrie 1918” din Alba Iulia*
4. *Chelidze, T., & Matcharashvili, Teimuraz & Abashidze, V. & Kalabegishvili, M. & Zhukova, Natalia. (2013): Real time monitoring for analysis of dam stability: Potential of nonlinear elasticity and nonlinear dynamics approaches, Frontiers of Architecture and Civil Engineering, Vol. 7, doi 10.1007/s11709-013-0199-5*
5. ****, Măsurători topogeodezice pentru U.C.C. la Baraj Oașa – tranșa august 2018*
6. *Agapie (Mereuță), I., Luca, M., Gherasim, P.M., (2022): Monitoring the Stability of Earthdams using Local Geodetic Networks, RevCAD 33/2022, Aeternitas Publishing House, pp. 7-16*
7. *Dreghici, A., Ienciu, I., Dimen, L., Barb, M.A., (2021): Monitoring the Road Displacements and Deformations, RevCAD 30/2021, Aeternitas Publishing House, pp. 21-28*