Aspects Regarding the Tracking of the Behavior in Time of Vâlsan Dam, Arges County, Romania

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Bulletin UASVM Horticulture 74(2)/ 2017

Print ISSN 1843-5254, Electronic ISSN 1843-5394

DOI:10.15835/buasvmcn-hort: 0030

ABSTRACT

This paper aims to highlight the behavior in time monitoring of a hydrotechnical construction by establishing the displacements compared to the base tranche and the previous tranche, processing these measurements and establishing conclusions on the behavior of the analyzed construction. The main purpose of this paper is to study if there are any displacements of the studied hydrotechnical construction between different measurements tranches. Field measurements were performed between September - December 2016, after which the data was processed at the office with specially developed programs for this purpose. For the micro-triangulation stage, respectively for measuring the directions and distances, were used Leica TS02 Plus R500 total stations. The measurement accuracy of this total station is 1" for directional determination and 1.5mm + 2ppm for distances. Tracking the behavior in time of hydrotechnical constructions are of great importance, because it can prevent many calamities like breaking the dam, floods etc.

Keywords: *dam, displacement, landmark, monitoring*

INTRODUCTION

Tracking of the behavior over time of different constructions can be achieved by experimental control of the way of behavior of a particular building under different weight loads and through a systematic tracking of the movements and deformations of the building or of the building elements in time. Subsequent alteration of the equilibrium conditions may result in the partial or total destruction of a building, can cause very large material damage and even loss of life (Onose *et al.*, 2009).

The measurements and observations made periodically on the constructions in nature, both in

the execution stage and in the exploitation phase, certify the correctness of the constructive system and of the calculation hypotheses envisaged in the design.

Based on the results obtained over time in building exploitation, laboratory and field studies and research, as well as information obtained from the destruction of buildings, a number of more frequent causes of displacements can be synthesized, and deformations that can be structured in general causes and particular causes. The general causes are related to the specificity of the geotechnical and hydrogeological conditions, as well as to the physico-mechanical properties of

the land from which the foundation ground is made. Particular causes may be due to the insufficiency of geotechnical and hydrogeological data, as well as accidental disturbance factors (earthquakes, hydrodynamic drive, difficult ground etc.) (Onose *et al.*, 2014).

The precision of measuring displacements and deformations of structures is determined firstly by those problems that need to be solved by analyzing the measured values of the displacement or deformation, taking into account both the practical and the scientific purposes of the research undertaken. It also depends on the destination and structure of the construction itself.

Depending on the deformation character, the topo-geodetic methods are classified as follows:

- I. Methods for determining horizontal displacements and deformations:
 - trigonometric method - microtriangulation;
 - the alignment method;
 - precision polygonal route method.
- II. Methods for determining vertical displacements and deformations:
 - high precision geometric method;
 - high precision trigonometric leveling method;
 - hydrostatic leveling method.
- III. Methods for determining the inclination of high construction:
 - vertical design method;
 - method of measuring horizontal angles at two or more base points
 - coordinate method;
 - the method of measuring horizontal and vertical angles at a single base point;
 - the method of measuring small zenith distances from two points at the base of the construction;
 - the method of measuring the foundation's composition.

The use of these methods can be done separately or combined, depending on the nature of the parameters that are required to be highlighted for the studied construction. The study of constructions using topo-geodetic methods is performed by making cyclic, angular and linear measurements from points outside the building to the points fixed on the construction (Moldoveanu, 2002).

Control points can be marked on buildings, on stable cliffs, or on concrete pilasters built on the ground.

If they are to be located on the building, it must be taken into account that they need to be consolidated, to be operated for at least five years and not to be exposed to various indoor or outdoor influences (exploitation shocks, floodplains). From this point of view, the public buildings best fit and the landmark is located near the corners where their stability is normal. In the speciality literature it is considered that if a construction does not interfere with continuous and increasing tasks this can be considered after a period of five years since its putting into operation stabilized (Sălăgean *et al.*, 2015; Brebu *et al.*, 2010).

As tracking marks recessed in construction, it can be used the steel landmark in the form of rods having a hemispherical head made of hard, stainless steel, on which it can be easily placed the leveling grid or optical prism. These rods are fixed with cement mortar in the holes drilled in the walls of the buildings. To preserve their original condition and to avoid scratching or damaging the tracking marks can be protected by special protective caps (Hann, 2014; Hann, 2015).

The control points fixed on the ground are of two types:

- surface markings;
- deep depth.

The surface control landmarks are constructed in the form of pyramidal truncated reinforced concrete beams with a square section base. The reinforced concrete terminal rests on a reinforced concrete soleplate with which it is connected by means of a metal reinforcement.

If the bench is not mounted in massive rock but on gravel or soft ground, its sole shall be at least 2.50 m deep (depth that is also variable depending on the depth of frost specific to the area). The reinforced concrete landmark which has the tracking mark (hemispherical pile) on which a leveling grid or topographic prism is placed, is protected against land movement by means of the reinforced concrete well provided with a metallic protective cap (Herban *et al.*, 2014).

When determining the depth at which such a point is to be assembled, two important indices will be taken into account: the level of groundwater specific to the area and the thickness of the frost (Popa, 2012).

In the case of soft soils or the existence of soft layers in the depth, or when the depth of macroporous soil layers exceeds 2m, it is

Fig. 1. Vâlsan Dam

necessary to use depth markers. Depth control marks are made in a variety of types and reach a few tens of meters deep. Adapting the technology of executing these types of landmarks can achieve very good results for topographic observations due to the very low displacements or variations of these landmarks. Depending on the site location, ground foundation stability and local geotechnical conditions, it can be said that these deep-sealed landmarks offer the certainty that they will not move over time and can be used for many years after the actual materialization on the ground.

MATERIALS AND METHODS

By measuring deformations means the totality of the measurements made to establish an elastic or permanent deformation of objects, under the influence of internal and external forces.

The Vâlsan Dam (Fig. 1) is located on the Vâlsan River and is located at approx. 1km upstream of the confluence with Dobroneagu River and approx. 2 km upstream of Brădet commune. The microtriangulation network pilasters from the Vâlsan dam were built down the dam in relatively stable areas. The type of pilasters is tronconic, with forced Wild type centering devices, not protected by thermal insulation. The sight marks, metallic and enamelled, are appropriate except for those that have been broken and rusted.

The technical characteristics of the Vâlsan dam are:

- Height measured above foundation 24 m.

- Dam crest length 99 m.
- Dam crest width 3 m.
- Width at the bottom of the dam 7 m.

The Vâlsan Dam allows the capture of the Vâlsan and Dobroneagu rivers and their management in the Vidraru reservoir lake through a subterranean gallery through the Vâlsan power plant and the Doamnei-Cernat-Vâlsan-Wolf Valley adduction.

The Vâlsan Dam was put into operation in 1968.

Planimetric measurements were made in the microtriangulation networks for tracking the displacements to the tracking marks located in the Vâlsan Dam.

For the azimuth observations from the microtriangulation network, we used the Wild T3 precision theodolite with forced centering, with the accuracy of the 1^{cc} reading device, and the pilasters were signaled by wild-type leveling grids.

During the observations, the water level in the lake was constant at 954.45 m. The air temperature ranged between 16°C and 18°C. The weather during the observations in the microtriangulation was variable, with the cloudy sky, with the light and light winds from the North direction, and the visibility was satisfactory.

After processing the field data and applying the statistical tests, it proved to be fixed points to the zero tranche the pilasters S1 and S2.

Compensation of the network (pilasters and parament marks) was performed in block using the least squares method.

Fig. 2. Microtriangulation network of Vâlsan Dam

Tab. 1. Coordinates of the pilasters and landmarks (Local coordinates system)

Crt. no.	Point name	X	Y
1	S1	265.6986	200.0020
2	S2	242.5549	170.2409
3	D1	204.4705	211.9029
4	D2	200.0169	200.0001
5	R1	194.8848	221.0790
6	R2	207.0435	233.5447
7	R3	220.5900	239.6497
8	R4	228.0534	241.1722
9	R5	235.6795	241.3052
10	R6	243.1197	240.0299
11	R7	257.0095	234.6117
12	R8	269.7267	222.7700

The accuracy in millimeters is:

- $M_{x_{max}} = \pm 0.5\text{mm.}$
- $M_{x_{min}} = \pm 0.2\text{mm.}$
- $M_{y_{max}} = \pm 0.6\text{mm.}$
- $M_{y_{min}} = \pm 0.4\text{mm.}$

The average standard deviation (network precision) is 0.61 mm.

RESULTS AND DISCUSSIONS

This network (Fig. 2) consists of:

- 4 pilasters (D1, D2, S1, S2);
- 8 tracking landmarks (R1, R2, R3, R4, R5, R6, R7, R8).

The coordinates of the the pilasters and landmarks were obtained in local coordinates system (Tab. 1).

In the micro-triangulation network performed for monitoring the behavior of Vâlsan Dam, were made angular and linear observations. After making all the measurements, they were processed in order to determine the horizontal displacements.

On the basis of the data collected with high-precision topographic equipment, a terrain register (Tab. 2) containing both the provisional

Tab. 2. Coordinates inventory

Point	Provisional coordinates	Correction [mm]		Compensated coordinates	St. Dev. [mm]		Axis el. [mm]		Or. el. [mm]
S1				200.0020 265.6986			Fix point		
S2				170.2409 242.5549			Fix point		
D1	211.9029 204.4705	-8.53	5.40	211.8944 204.4759	0.35	0.40	0.46	0.27	140.72
D2	200.0001 200.0169	-14.70	23.06	199.9854 200.0400	0.35	0.42	0.46	0.29	134.08
R1	221.0790 194.8848	-9.83	4.33	221.0692 194.8891	0.50	0.51	0.64	0.33	148.39
R2	233.5447 207.0435	-11.30	3.15	233.5334 207.0467	0.55	0.43	0.60	0.36	167.76
R3	239.6497 220.5900	-11.13	1.40	239.6386 220.5914	0.53	0.39	0.56	0.35	174.50
R4	241.1722 228.0534	-10.93	0.69	241.1613 228.0541	0.52	0.36	0.54	0.33	178.01
R5	241.3052 235.6795	-9.23	-1.54	241.2960 235.6780	0.51	0.34	0.53	0.31	181.74
R6	240.0299 243.1197	-7.84	-2.60	240.0221 243.1171	0.50	0.31	0.51	0.29	185.72
R7	234.6117 257.0095	-5.14	-3.11	234.6066 257.0064	0.49	0.24	0.49	0.24	196.58
R8	222.7700 269.7267	-1.62	-3.01	222.7684 269.7237	0.47	0.20	0.49	0.16	17.21

Tab. 3. Horizontal directions

Station	Vised point	Measured direction	Correction [sec]	Compensated direction	Orientation
D2	R6	352.344180	-0.85	352.344095	52.327846
	R7	365.250600	0.82	365.250682	65.234432
	R8	379.899200	2.98	379.899498	79.883249
D1	S1	0.000000	3.42	0.000342	112.214846
	S2	40.638550	-1.89	40.638361	152.852110
	D2	110.485580	3.47	110.485927	222.699673
	R1	236.388730	-1.49	236.388581	348.602330
	R2	295.314130	-0.14	295.314116	7.527867
	R3	321.286930	-0.27	321.286903	33.500652
	R4	330.959380	0.20	330.959400	43.173148
	R5	339.677150	-1.30	339.677020	51.890768
	R6	347.728950	-0.45	347.728905	59.942653
	R7	361.806350	0.95	361.806445	74.020193
	R8	377.273400	-2.51	377.273149	89.486897

Station	Vised point	Measured direction	Correction [sec]	Compensated direction	Orientation
S2	S1	169.928930	-4.68	169.928462	42.078221
	D1	80.702330	0.21	80.702351	352.852110
	D2	66.714550	-3.25	66.714225	338.863984
	R1	79.893150	4.86	79.893636	352.043394
	R2	95.302080	1.41	95.302221	367.451979
	R3	108.336930	0.50	108.336980	380.486738
	R4	115.010500	-0.01	115.010499	387.160258
	R5	121.707780	1.80	121.707960	393.857718
	R6	128.362800	3.27	128.363127	0.512885
	R7	141.910980	-4.11	141.910569	14.060328
S1	S2	376.938730	3.91	376.939121	242.078221
	D1	47.075580	-5.89	47.074991	312.214090
	D2	34.075580	2.09	34.844809	299.983903
	R1	53.270400	2.23	53.270623	318.409722
	R2	67.923950	-0.87	67.923863	333.062962
	R3	80.756930	-0.32	80.756898	345.895996
	R4	87.698430	0.03	87.698433	352.837531
	R5	94.842030	-1.12	94.841918	359.981017
	R6	102.156550	-1.66	102.156384	367.295483
	R7	119.193800	1.76	119.193976	384.333075
	R8	146.001200	-0.15	146.001185	11.140284

Tab. 4. Displacements on each measurement tranche

Landmark	Tranche July 2001		Tranche June 2007		Tranche June 2009		Tranche September 2011		Tranche June 2013		Tranche May 2015		
S1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
D1	-1.1	0.8	-1.0	0.5	0.1	-0.6	-1.4	-0.3	0.0	0.0	0.3	-1.8	
S1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
D2	32.6	-8.1	32.3	-9.1	35.9	-10.4	35.0	-10.7	15.5	-7.2	37.5	-12.7	
R1	-1.0	-1.2	-1.7	-1.8	0.2	-3.1	-1.1	-2.8	-2.1	1.0	0.6	-4.8	
R2	-2.0	-0.4	-3.0	-0.2	-0.4	-3.2	-1.9	-2.5	-0.9	-1.4	-0.8	-4.8	
R3	-1.5	-0.5	-2.3	0.3	-0.3	-3.6	-1.6	-2.1	-0.9	-0.9	-0.9	-4.8	
R4	-0.7	0.0	-1.3	0.9	0.1	-3.4	-1.2	-1.4	-0.8	-0.7	-0.6	-4.5	
R5	-1.7	1.0	-2.6	2.1	-1.9	-2.0	-2.8	-0.7	-1.5	0.8	-2.5	-3.2	
R6	-1.4	1.7	-1.7	2.7	-1.7	-1.1	-2.5	0.4	-1.7	1.3	-2.5	-1.7	
R7	-0.9	2.4	-0.9	3.3	-1.4	0.5	-2.0	1.5	-1.0	2.0	-2.1	0.3	
R8	1.4	4.5	1.5	4.5	0.9	3.5	0.7	4.5	0.3	3.4	0.1	3.5	
Err	E.U.P	4.2 ^{cc}		4.4 ^{cc}		3.0 ^{cc}		Network precision 0.89 mm		Network precision 1.81 mm		Network precision 0.61 mm	
	Max	±0.6	±0.7	±0.6	±0.7	±0.4	±0.5	±0.8	±0.8	±1.3	±0.5	±0.5	±0.6
	Min	±0.2	±0.4	±0.3	±0.4	±0.2	±0.3	±0.3	±0.5	±0.4	±0.2	±0.2	±0.4

coordinates and the compensated coordinates of the pilasters and tracking marks was made.

The compensated coordinates of the pilasters and tracking marks were obtained by applying to the provisional coordinates the calculated corrections.

From table 2 it can be seen that the maximum correction applied to the provisional coordinates following the calculations was 23.06 mm, correction applied to the provisional coordinates of point D2.

Based on the measured directions from each station point (D1, D2, S1, S2), were calculated the angular corrections which were applied in order to obtain the compensated directions (Tab. 3) based on which the orientations were determined.

The largest angular correction is -5.89 seconds and was applied to the direction measured from station point S1 to the point D1.

Finally, the calculations of horizontal displacements of the Vâlsan dam were made. The calculation of these displacements was made using both the measurement data from the base tranche and the current tranche measurements.

Table 4 shows the horizontal displacements for each tracking track in multiple measurement tranches (6 measuring tranches: July 2001, June 2007, June 2009, September 2011, June 2013 and May 2015).

CONCLUSIONS

Due to the modern technologies and techniques in the field of engineering topography, observations of the movements of any structure are permitted using modern surveying techniques and tools with high accuracy and precision.

It is recommended to repair the S2 pilaster, which began to degrade (grind). The plaster has to be rebuilt, because the metal reinforcement appeared due to the grinding of concrete in the pilaster.

In order to carry out in good conditions the following microtriangulation tranches, the visibility gauge between the microtriangulation pilasters and the parapet traps embedded in the Vâlsan dam must be enlarged.

The displacements of Vâlsan Dam fall into the tolerances and do not represent a danger to the dam.

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