ASPECTS REGARDING THE MONITORING OF WEIGHT DAMS BY GEODETIC MEASUREMENTS

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***Abstract**: The paper refers to tracking stabilities of weight rockfill dams placed on Someşul Cald river, through geodetic measurements. Tracking dam stability is achieved in terms of planimetric and altimetric. For panimetric tracking was used the micro-triangulation method, the trilateration method and combined methods. In terms of altitude was used the geometric geodetic leveling method. For the case study was chosen Beliş-Fântânele dam weight. For its tracking was acheived a micro-triangulation network downstream and one upstream. In determining the azimuth and zenith observations we used a precision total station Leica TS 30. Processing geodetic observations was performed by the method of indirect measurements.*

***Keywords:** micro-triangulation network, trilateration network, monitoring.*

1. Introduction

Monitoring dams, the foundation rocks and slopes of the accumulation lake presents vitally importance due to the hazards emanating by the destruction energy of water at dam failure. Also, monitoring and predicting the behavior of hydraulic structures and their surrounding areas are of great importance in terms of environmental protection, due to both environmental impact and set targets potential environmental risks. Monitoring and controlling the dams condition involves setting up a system which realize the acquiring of geometrical, mechanical and physical parameters of dams, processing and interpretation of observed data, creating databases that analyze and predict the behaviour of dams.

Monitored parameters describing the dam-foundation system response to a particularly environmental action differs depending on the type of dam. [1]

In the case of concrete dams may be mentioned: absolute displacement of the dam and foundation, relative movement between plots, changes in the temperature of the dam body, the deformation state of the dam and foundation work, the condition of failure, interstitial pressure and under-pressure, flow infiltration and so on. [2]

In the case of filling dams, main parameters monitored are: travel and subsidence dam-foundation system during construction and operation, water seepage in the dam, pore water pressure, total and effective stress state, seepage through slopes curve position infiltration in slopes, slope movements, the strain and efforts in the concrete works associated to the filling dam, unloaders surface, bottom emptying etc.

Monitoring system design must take into account the structure of the dam-foundation as a unified system and equipment shall record the behavior of each subsystem separately.

Systematic monitoring and visual inspection is the best protection against incidents or dam failure. Causes of dam failures are due mostly to geological conditions, negligence in execution and maintenance works and their age.

In the field of concrete dams the main causes of their failure were the waste water disposals over the dam, the dam foundation and shoulder instability.

In order to take the appropriate measures necessary to avoid dam failure, the primary information provided by the instrumentation and control must be sent immediately those responsible for dam safety. [9]

Organizing the supervision of dams behaviour must comply with the legislation in force in Romania (Law 10/1995, HG no. 766/1997, Methodological Norms P130/1999, Law 466/2001, NP 087-03, Law no.13/2006 and other 14 technical norms (Technical Norms for Hydro-technical Works).

Hydraulic structures behaviour analysis is performed at several levels of competency: dam (local level) territorial unit (hydraulic system, steering basin, branch hydro etc.) central unit (national level).

According to the Ministry of Environment, of all dams with reservoirs in Romania, 276 dams are included in the group of large dams according to the definition ICOLD (International Commission of Large Dams), commission founded in 1928 and formed of 6 countries (Switzerland, France, Italy, GB, USA and Romania), http://www.mmediu.ro

In the Ministry of Environment operates the National Commission on Dams Safety (NCDS), an advisory body created to regulate, coordinate, guide and track the evaluation of dam safety.

In terms covered by current legislation, dam safety assessment is performed by certified technical experts, approved by the Ministry of Environment.

2. Materials and Methods

This paper aims dam stability monitoring of the Beliş Fântânele dam which was made by a well established programme according to: the season, the atmospheric condition, the lake level etc.

The Beliş Fântânele dam (Figures 1 and 2) is a rockfill gravity dam with concrete mask on the upstream side with the following features:

Coronament height	996,00 m d. m.
Dam height	95,50 m
Length (at coronament)	400 m
Width (at base)	264 m
Volume	2.315 thousand m^3

Fig.1 Beliş-Fântânele upstream side

Fig.2 Beliş-Fântânele downstream side

Geodetic network for dam tracking was designed in the years 1970-1974, and is composed of five pilasters located downstream of the dam, four pilasters on the upstream and two pilasters at the ends of the coronament.

Pilasters related to the micro-triangulation network on which are installed alternatively the total station and the prisms are of conical type, with Wild centering devices which are corectly mounted and executed (Figure 3.)

Fig.3 Tronconic pilaster (PII)

Fig.4 Leveling mark placed on the coronament

The targeting marks (Figures 5 and 6) present a different form depending on the downstream or upstream side.

Fig.5 targeting mark placed in the downstream side

Fig.6 targeting mark placed in the upstream side

Micro-triangulation method used to track horizontal movement is actually a relatively small triangulation with sides of 100-300 m, but keeps the angles measurement accuracy from the triangulation of higher order. [3]

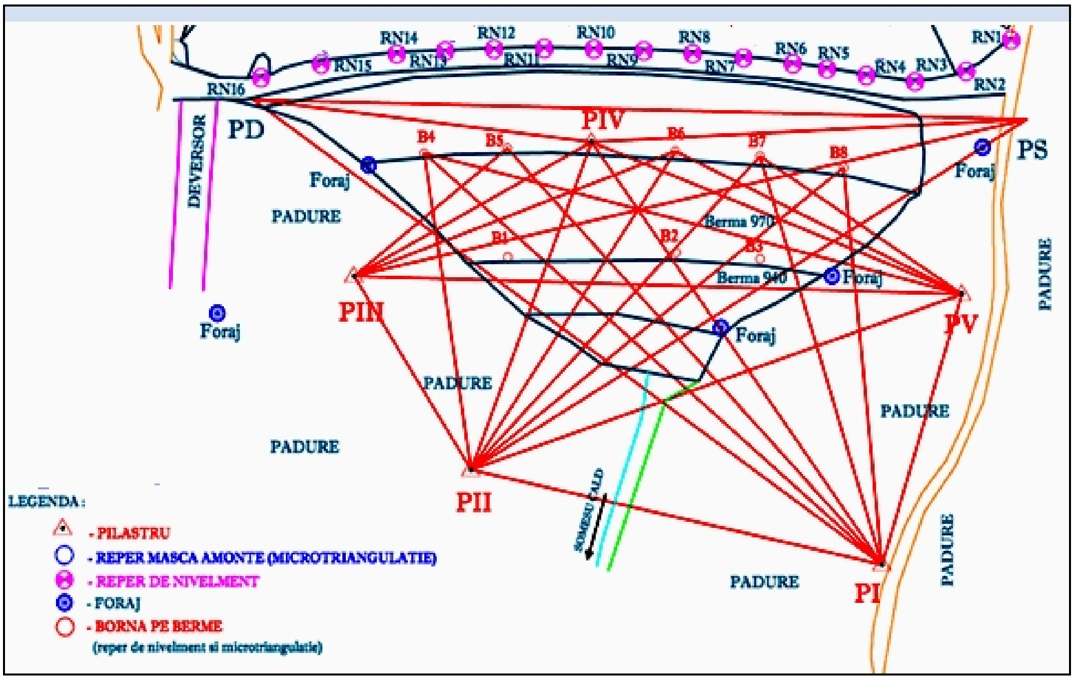

Fig.7 Micro-triangulation network from downstream

Planimetric measurements to determine the displacement of the tracking networks and in order to determine the movements of the targeting marks located on the upstream side were performed with the total station Leica TS 30 that has a 0.5" precision.

An important condition for accurate determination of absolute displacements of the dams is the stability of the geodetic observation points, that's why, the first step is to verify the stability of the tracking stations. To do this, perform observations for azimuth and distance between pilasters downstream the micro-network (PI, PII, PIII, PIV, PV, PD, PS). [4]

To determine the subsidence of the levelling marks were performed three geometric levelling polygonal routes with departure from a mark considered fixed, and closing on the same departure mark:

- the first polygonal route was made on the dam coronament, where are located 16 leveling marks, starting from the mark situated at the base of pilaster IV, which is considered fixed;

- the second polygonal route was made on the first horizontal step on the downstream side of the dam, where are located 5 levelling marks which are used in determining planimetric and altimetric measurements based on the mark located at the base of pilaster PIII, which is considered fixed. [5]
- the third polygonal route was made on the second horizontal step on the downstream side of the dam, where are located 3 leveling marks, starting from the mark located at the base of pilaster PIII, which is considered fixed.

In general, processing of geodetic observations in triangulation networks is achieved by Gauss Markon model, which is formed from a functional model for processing and a stochastic model. [6]

For every epoch can form a functional system that takes the form:

$$v_i = A_i x_i + l_i,\ P_i; \quad i = 1,2...q$$

where:
v_i - correction vector
l_i – free terms vector
A_i – coefficient matrix

Stochastic or statistical model contains random variables corresponding to uncontrollable factors that influences the measurements. [7]

$$C_m = \sigma^2 Q_m$$

where:
C_m - matrix of variance - covariance
σ^2- variance of unit weight
Q_m – coefficients measurements matrix

As hypothesized, the movement in time of the network points in the q epochs, the vector of the unknowns x has no links between groups, which makes no sense for solving in block. The unknowns x_i vectors computed at different epochs are calculated by the relationship:

$$x_i = (A^T PA)^{-1} A^T Pl$$

The marks displacements are obtained as a difference between the vector of the unknowns x_i which are calculated at different epochs.

$$d_{i,i+1} = x_{i,i+1} - x_i$$

Precision indices:

$$m_0 = \pm\sqrt{\frac{V^T PV}{n-k}}$$

$$m_{x1} = \pm m_0 \sqrt{Q_{ii}}$$

3. Results and Discussions

Based on geodetic observations made in the micro-triangulation network of Beliş-Fântânele dam was pursued the stability of tracking stations downstream of the dam and the evolution in time of the tracking marks, located on the downstream of the dam. [8]

COMPENSATION RESULTS (free networks)

Average standard deviation (network precision): 2.27 mm.

Point	Provisionally Coordinates	Cor. [mm]	Compensated coordinates	St.dev. [mm]	Axe el. [mm]	Or.el. [grd]
PI	796.3631	-2.21	796.3609	1.63	2.33	142.98
	507.3803	0.22	507.3805	1.91	0.95	
PII	753.7017	-2.03	753.6997	1.15	1.86	71.41
	699.8219	-2.17	699.8197	1.72	0.91	
PIII	666.3195	-1.62	666.3179	1.03	2.48	102.38
	755.4734	-2.53	755.4709	2.48	1.02	
PIV	605.7958	11.07	605.8069	1.27	1.71	127.75
	642.5016	-3.85	642.4978	1.62	1.15	
PV	674.3654	0.42	674.3658	1.16	2.49	98.21
	466.3561	-1.74	466.3544	2.49	1.16	
PS	595.5830	2.10	595.5851	1.62	1.90	53.51
	435.5497	3.34	435.5530	1.68	1.35	
PD	586.6279	-0.96	586.6269	1.50	1.81	144.10
	803.4964	5.69	803.5021	1.60	1.24	

COMPENSATION RESULTS (constrained networks)

Average standard deviation (network precision): 4.09 mm.

Point	Provisionally Coordinates	Cor. [mm]	Compensated coordinates	St.dev. [mm]	Axe el. [mm]	Or.el. [grd
PI			796.3631	PUNCT FIX		
			507.3803			
PII			753.7017	PUNCT FIX		
			699.8219			

PIII			666.3195	PUNCT FIX		
			755.4734			
PIV	605.7958	12.40	605.8082	0.64	1.00	84.66
	642.5016	-2.04	642.4996	0.98	0.61	
PV	674.3654	1.36	674.3668	1.16	1.16	3.23
	466.3561	-2.93	466.3532	0.81	0.81	
PS	595.5830	2.98	595.5860	1.23	1.44	45.80
	435.5497	1.78	435.5515	1.16	0.88	
PD	586.6279	1.12	586.6290	1.22	2.29	116.68
	803.4964	5.86	803.5023	2.23	1.10	

COMPENSATION RESULTS
block leveling - constrained network
Average standard deviation (network precision): 0.36 mm

No. crt	Point name	Type	H prov. [m]	Cor. [mm]	H comp [m]	St.dev. [mm]
1	PII	NEW	942.3130	-1.77	942.3112	0.45
2	PIII	NEW	969.7760	15.48	969.7915	0.41
3	R1	NEW	996.1374	-7.71	996.1297	0.15
4	R2	NEW	995.9870	-15.31	995.9717	0.17
5	R3	NEW	996.0570	-63.67	995.9933	0.20
6	R4	NEW	996.0982	-124.68	995.9735	0.21
7	R5	NEW	996.1210	-165.53	995.9555	0.23
8	R6	NEW	996.1590	-199.58	995.9594	0.25
9	R7	NEW	996.1889	-238.92	995.9500	0.26
10	R8	NEW	996.1827	-274.31	995.9084	0.28
11	R9	NEW	996.2301	-287.51	995.9426	0.29
12	R10	NEW	996.2333	-296.30	995.9370	0.30
13	R11	NEW	996.1715	-286.13	995.8854	0.31
14	R12	NEW	996.1099	-266.36	995.8435	0.33
15	R13	NEW	996.0925	-232.52	995.8600	0.34
16	R14	NEW	996.0670	-182.47	995.8845	0.35
17	R15	NEW	996.0168	-90.85	995.9260	0.36
18	R16	NEW	996.2721	-33.47	996.2386	0.37
19	B1	NEW	940.4034	-17.49	940.3859	0.49
20	B2	NEW	940.1562	-22.34	940.1338	0.50
21	B3	NEW	940.3634	-19.22	940.3442	0.50
22	B4	NEW	970.4376	-12.02	970.4256	0.44
23	B5	NEW	970.3360	-21.28	970.3147	0.46
24	B6	NEW	970.1374	-25.31	970.1121	0.48
25	B7	NEW	970.0519	-20.79	970.0311	0.48
26	B8	NEW	970.1806	-11.74	970.1688	0.47
27	PI	FIX			1002.8680	
28	PIV	NEW	1003.0950	-1.45	1003.0935	0.09

4. Conclusions

In order to obtain displacement parameters with high accuracy, each item will have covered a minimum of three stations, and the angles of intersection to be more favorable, respectively will avoid very skewed visas.

Using the *APORT* software for processing the geodetic observations, facilitated the establishment of fixed points to the series of measurements made on the pilasters network.

By using high precision surveying equipment, a suitable method for measuring the angles and rigorously compensating the measured data yielded the most probable values of the displacement, tracking stations and sight marks.

In the case of compensating the micro-triangulation as a free network, the values obtained were millimeter, and in the case of constrained network , the values obtained for the fixed points were of the order of 2-4 millimeters.

5. References

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