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APPLICATION OF THE CONDOR STATISTICAL MODEL IN THE CASE OF THE CLOCOTIȘ ARCHED DAM FROM GORJ COUNTY

Albert Titus CONSTANTIN [1] Marie-Alice GHIȚESCU [1] Cristina ALEXANDRU [1]

Abstract: The paper presents the special follow-up (category of importance of the dam: B) of the time behaviour of the Cinciș dam by evaluating (through direct observations and measurements), some parameters that define the state and evolution of the safety of the dam, in relation to actions to which he is subjected. Thus, it was verified if the variables that identify the behaviour of the structure as well as those related to the environmental and operational conditions are in the range of values obtained previously and if they are consistent.
Keywords: arched dam, measurements

1. GENERAL CONSIDERATIONS

The Cinciș reservoir (Teliuc lake) is located on Cerna River, in Cerna-Mureș catchment (at East of Poiana Ruscă mountain) at 310 m from Cerna River and Runcu stream junction, respectively at 6,5 km from Zlaști stream junction (Hunedoara county). Cinciș dam is an arch concrete dam, with a height of 48 m, measured foundation base. The construction works were executed in 1961 – 1964 period, partially operating in 1962, and in 1964 put into operation at total capacity.

Figure 1. Plan view of Cinciș dam

The Cinciș reservoir uses are as following:

1. Water supply for industrial units: Siderurgia S.A. Hunedoara (nowadays Arcelor Mittal Hunedoara), Q_{min} = 1,44m^3/s.
2. Hydroelectric energy production through S.H.P.P. (small hydropower plant) located at the Cinciș dam toe, which was never in use, and owned by Hidroelectrica S.A. company. From October 2011 was ensured the water requirement for the S.H.P.P. downstream of Cinciș dam, owned by Uzinsider General Contractor S.A. București.
3. Flood mitigation purpose: since downstream of Cinciș reservoir are the junctions of Cerna River with Runcu and Zlaști streams, both located upstream of Hunedoara municipality and industrial platform, and the high-water spillways are located at two different elevation levels, resulting a flood mitigation volume of 8,66 million m^3 of water, from a total volume of 43,3 million m^3. The flood mitigation peak at Hunedoara is made by regularising the Cerna River flows, and due the delay of flood peaks on Runcu and Zlaști streams.
4. Securing a baseflow downstream of Cinciș dam. On the 310 m between Cinciș dam and Runcu stream junction is ensured a downstream flow of 50l/s through the bottom outlet by-pass.

The Cinciș dam is a concrete arch dam. The total height is 48 m from the base of the foundation, including the foundation depth. According to the L/H ratio = 4,6 can be considered a weight arched dam. Cinciș dam was included at the design time in class I of importance, the spillways being designed at $Q_{0.1\%}$ = 340m^3/s and verified at $Q_{0.01\%}$ = 450m^3/s. The importance category according with the Technical standard NTLH 021 is **B**, dam of high importance, which requires special follow-up.

Monitoring with the measurement and control devices (MCD) of external stress is made following the parameters:

- Measurements of water level in the reservoir done with stage gauge, located on the upstream dam face.
- Air temperature measurements
- Precipitations measurements (rain gauges, and snow density measurements.

Monitored parameters and measurement devices for tracking the barrage works response and their foundation behaviour while in operation:

- Absolute displacements: topographical and geological measurements (mm) are carried out with the help of micro - triangulation of geodetic networks and precision levelling

[1] Politehnica University of Timişoara, Department of Hydrotechnical Engineering, Spiru Haret Street, no. 1A, 300022, Timişoara, Romania, albert.constantin@upt.ro, alice.ghitescu@upt.ro, cristina.alexandru@student.upt.ro

- Relative displacements: measurements at the bolts strain gauges and pendulum (mm).

Table 1 shows the measuring and control devices (MCD) provided in the project, mounted and in operation:

Table 1. Measuring devices

Crt. no.	Device name	Quantity (pcs.)		
		Provided	Mounted	In Operation
1.	Pendulum (plot 9)	1	1	1
2.	Stage gauge	1	1	1
3.	Thermometer	1	1	1
4.	Hydrometer	3	3	-
5.	Telepresmeter	14	14	-
6.	Teleformeter	134	134	-
7.	Micro-triangulation landmarks	15	15	15
8.	Levelling landmarks	10	10	8
9.	Pillars of micro-triangulation	6	6	6
10.	Deformed bolts	19	18	18

Starting from 1990 the measurements at telepresmeter and teleformeter were stopped as the hydrometers were clogged. Huggenberger strain gauge, required for performing measurements at the deformation bolts from Cinciș dam, was broken in March 2015. In 2016 a MGM 500-0,001mm device was purchased, with a rage of 12,5mm.

Through" WATMAN-Stage I Automatic gauges located at the reservoirs" project at Cinciș dam in 2015 the following monitoring devices and equipment were installed:

- Water level transducer in the reservoir – the stage sensor radar type, located at the upstream spillway pillar on the left bank
- Precipitation transducer
- Temperature transducer – both air temperature and rain sensors are mounted on the same metal support.
- The tele - pendulum mounted in MCD box with direct pendulum
- Telepresmeter automatic reading – 13 pcs. Arranged as follows: at the console base in the plots of powerplant 8 (P01 and P02), 10 (P03 and P04) and 12 (P05 and P06); at the arches in plots 2 (P11 and P12) and 18 (P13) at 286maSL elevation and in plots 5 (P7 and P8) and 14(P9 and P10) at elevation 267maSL.
- Spillway and stage sensor located in the downstream bed of the energy dissipator.
- Data acquisition and transmission system: datalogger, GSM modem, data asset PC and video monitoring system at Cinciș dam.

Figure 2 shows the measure and control devices (MCD) plan view displacement.

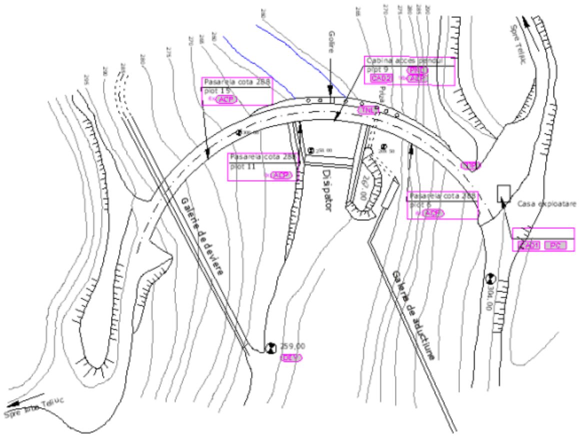

Figure 2. Dam plan view, and MCD displacement.

During the analysed operating period (October 2019-October 2020) at Cinciș dam no special events were recorded, the exterior stresses had expected values, within the previous recorded range period and below the design values.

Between 12-20 of June 2020, when it was recorded an increase in the reservoir levels up to 294,95maSL (with 1,45m above retention normal level – 20.06.2020) due to the transition of a moderate flood. The attenuated flood volume was 6.5hm^3. The maximum tributary flow was 31.27 m^3/s and the maximum flow discharged through the spillway was 9.36 m^3/s.

2. MEASURED PARAMETERS BEHAVIOUR

2.1. Relative horizontal displacements measured with direct pendulum

To follow the dam deformations in horizontally plan, a direct pendulum was installed on plot 9. The measurements are made both manually and automatic (WATMAN project).

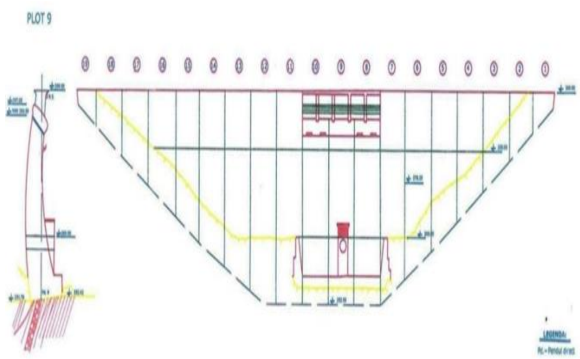

Figure 3**.** MCD displacement in main dam cross section

Regarding manual measurements, it is specified that the reading device, the coordimeter measures displacements relatively of the crest (300maSL altitude) if an intermediate elevation (268 maSL) is compared with the measured point at the base of the dam. The pendulum is blocked at 268 maSL elevation and performs oscillation for lengths of 48m and 16m. The figures below show the evolution movements in the two directions (upstream – downstream and right bank – left bank) in relation to the level variation in the lake and the daily air temperature, during the period of exploitation 2009 – October 2020.

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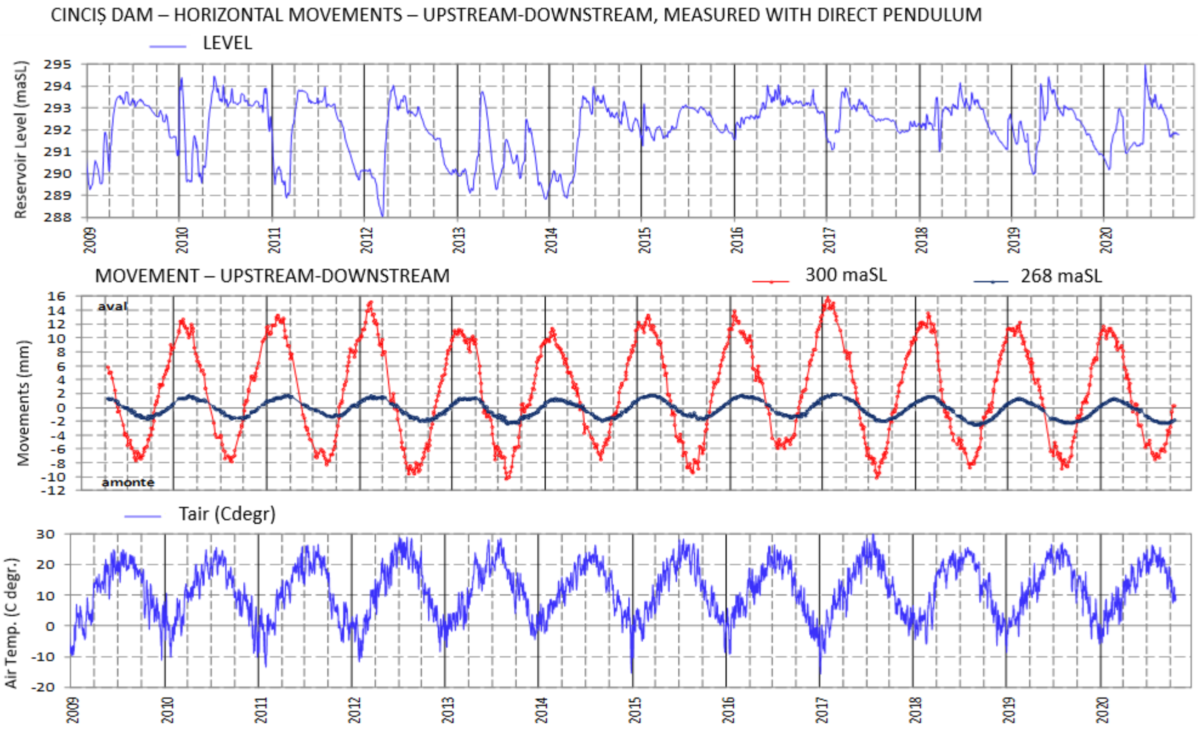

Figure 4. Horizontal displacements on upstream – downstream direction

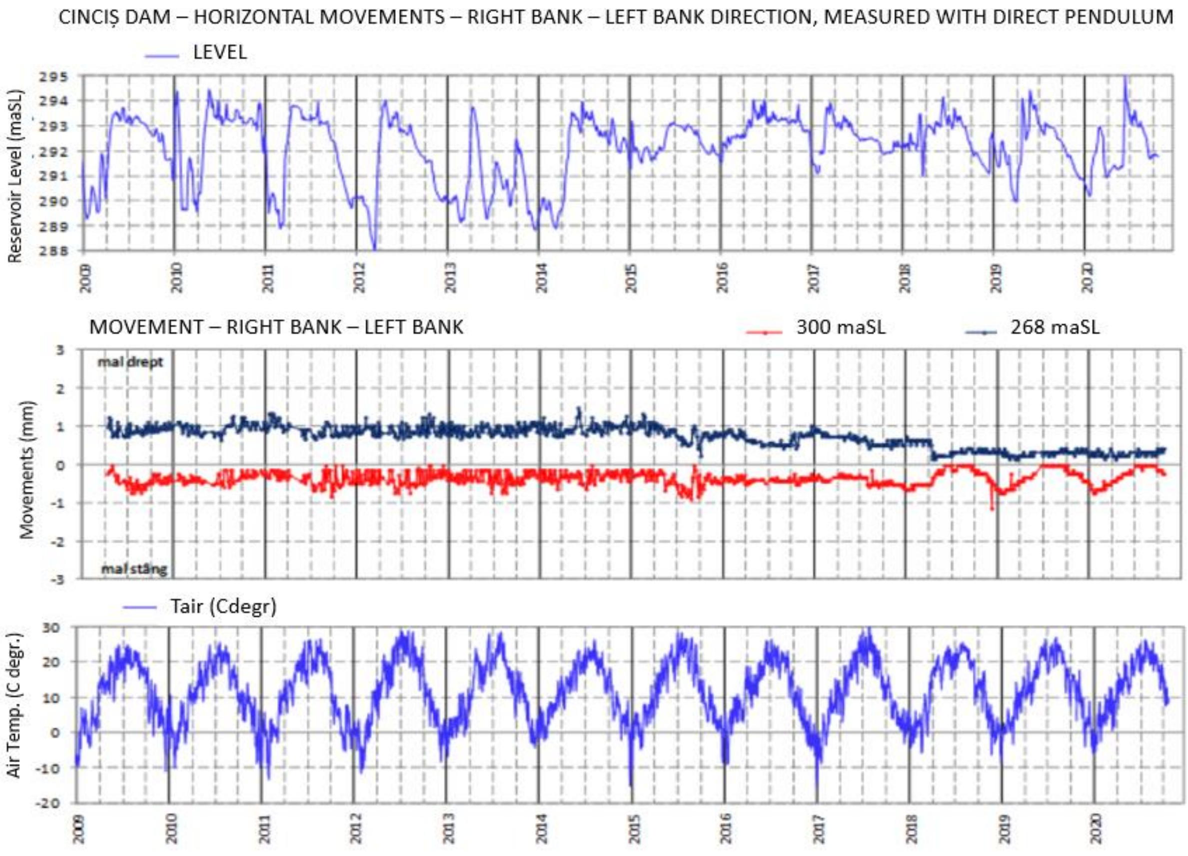

Figure 5. Horizontal displacements on right bank – left bank direction

The table below show the horizontal displacements on upstream – downstream direction, measured with direct pendulum (mm).

Table 2

Period (year)	”Y” downstream- upstream (mm)							
	300 maSL				268 maSL			
	Min	Max	A	Med	Min	Max	A	Med
2010-2016	-10.3	15.2	25.6	2.7	-2.4	1.7	4.1	-0.1
2017	-10.2	16.1	26.2	2.2	-2.0	1.9	3.9	-0.2
2018	-8.7	13.6	22.3	2.2	-2.5	1.5	4.0	-0.6
2019	-8.9	12.3	21.2	2.2	-2.2	1.2	3.4	-0.7
2020	-7.5	11.6	19.1	1.9	-2.3	1.2	3.5	-0.5

The table below show the horizontal displacements on right bank – left bank direction, measured with direct pendulum (mm).

Table 3

Period (year)	”Y” right bank – left bank (mm)							
	300 maSL				268 maSL			
	Min	Max	A	Med	Min	Max	A	Med
2010-2016	-0.9	-0.1	0.8	-0.4	0.2	1.5	1.3	0.9
2017	-0.6	-0.2	0.5	-0.4	0.4	0.9	0.5	0.6
2018	-1.1	-0.1	1.1	-0.3	0.1	0.7	0.6	0.4
2019	-0.8	-0.1	0.7	-0.3	0.1	0.4	0.3	0.3
2020	-0.8	-0.1	0.7	-0.3	0.1	0.4	0.3	0.3

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Where Min = minimum, Max = maximum, A = amplitude, Med = medium,”-” sign represents displacement towards upstream, right bank respectively.

The analysis of the horizontal displacements graphs shows the following:

1) Upstream – downstream movements are influenced by the seasonal thermal factor. This shear stress is significant, measurements showing seasonal variation.
2) The displacements measured during the analysed period falls within the range values from the previous functioning period.
3) The extreme values, slightly different, from 2017 are due to the fact that on January 10th, 2017, were recorded the lowest temperatures on site (-15.8ºC) from the entire period of analysis (2009 – 2020), and on August 3rd, 2017, the highest temperatures on site (30.5ºC) from the entire analysed period.
4) In the right bank – left bank direction, the measured displacements are small, under millimetres, the influence of external factors being in the accuracy range of the measurement system.
5) Starting with 2018, at the measurement point, elevation of 300maSL, the displacements on the right bank – left bank direction were influenced by the seasonal thermal factor, which demonstrates a qualitative improvement in the measurement’s performance.

In conclusion, it can be stated that the dam had, from the point view of horizontal displacements, a normal behaviour over time, consistent with the demands to which it was subjected.

2.2. Absolute geodetic measured displacements

Topo - geodetic measurements are carried out at the monitoring points on the upstream face of the dam at the two elevation levels of 300maSL and 268maSL. These measurements are performed by a specialized and authorised company. Topogeodetic works consist of:

- Horizontal displacements tracking of the monitoring points located on the downstream face of the dam.
- Land recognition. This operation precedes the topographical measurements, and aims to evaluate the state of the micro triangulation network, and the monitoring points.
- Drawing the azimuthal observations plan, and making observations in the network. When determine the number of readings in each pillar it is aimed that each landmark to be observed from minimum four station points, to obtain angles of optimal intersection, avoiding the declined readings. Azimuth observations are performed with precision theodolite, by complete reading series with four origins, both in the network and in landmarks.
- Next are positioned six pillars of micro triangulation PI, PII, PIII, PIV, PV, PVI and are observed the 16 landmarks on the downstream face.
  - Observing the micro triangulation points is made on the Wild type level gauging stations.
  - Observations in the network are carried out only in geodetic time conditions.
  - Processing and compensation topo-geodetic measurements to obtain the values more probable of the measured qualities and their accuracy. Compensation of the micro-triangulation network and the landmarks are carried out with the method of the smallest

squares. Following data offset, standard deviation of the network support was 2.41 mm, and a 8.91 mm tracking grid. Displacement station points and landmarks are deduced by comparing deformation measurements from an instalment of measurements to the next.

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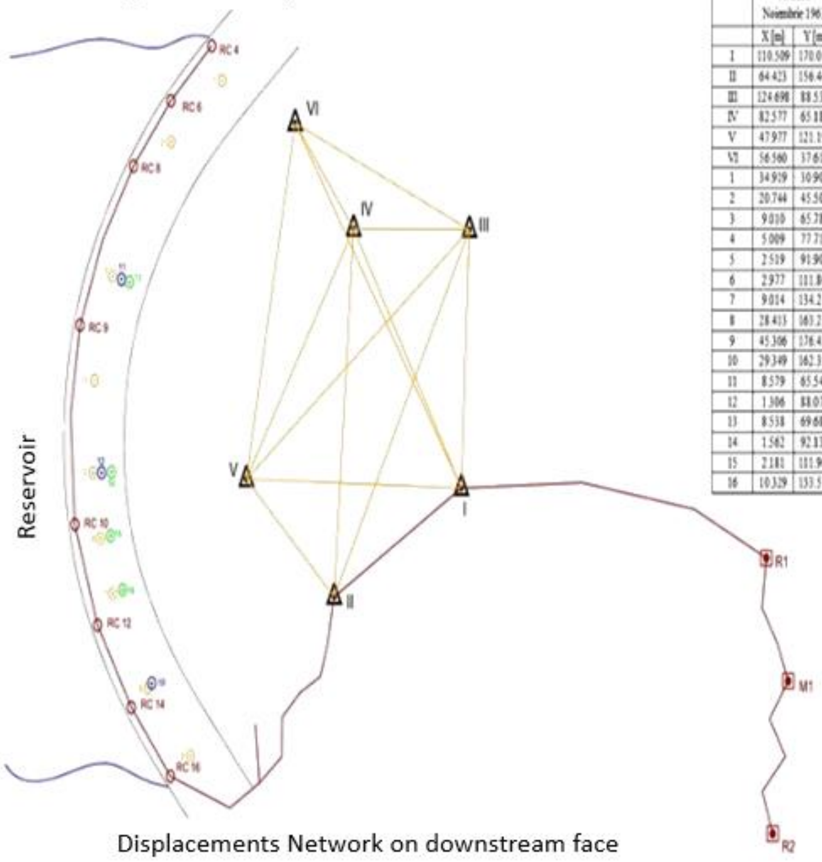
CINCIȘ DAM – DISPLACEMENT POINTS MONITORING

Monitoring displacements network

Level micro-triangulation draft plan view Scale 1:1000



	Coordonate de referinta Noiembrie 1963		Coordonate determinate Septembrie 2013	
	X [m]	Y [m]	X [m]	Y [m]
I	110.509	170.055	110.508	170.054
II	64.423	156.469	64.422	156.464
III	124.698	88.533	124.699	88.533
IV	82.577	65.183	82.577	65.182
V	47.977	121.190	47.977	121.188
VI	56.560	37.616	56.562	37.616
1	34.919	30.902	34.921	30.899
2	20.744	45.503	20.742	45.497
3	9.010	65.789	9.007	65.785
4	5.009	77.719	5.003	77.715
5	2.519	91.909	2.513	91.905
6	2.977	111.806	2.971	111.803
7	9.014	134.219	9.006	134.220
8	28.413	163.236	28.407	163.237
9	45.306	176.451	45.304	176.448
10	29.349	162.351	29.345	162.350
11	8.579	65.542	8.579	65.538
12	1.306	88.075	1.304	88.071
13	8.538	69.684	8.539	69.680
14	1.562	92.131	1.565	92.131
15	2.181	111.902	2.181	111.898
16	10.329	133.576	10.328	133.575

Reperi fundamentali si reperi de coronament		
	Noiembrie 1963	Septembrie 2013
Punct	H [m]	H [m]
TR	272.225	272.225
N0	322.17315	322.1648
RC 4	300.1128	300.1053
RC 6	300.0953	300.0875
RC 8	300.1232	300.1158
RC 9	300.1539	300.1442
RC 10	300.1064	300.1005
RC 12	300.1051	300.0975
RC 14	300.1525	300.1453
RC 16	300.0818	300.0751

Displacements Network on downstream face

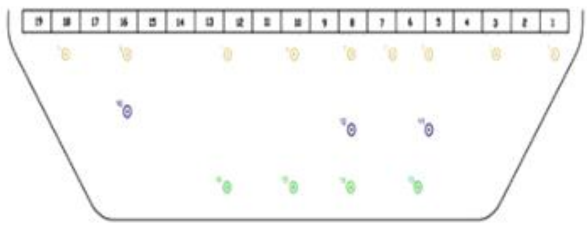


Figure 6. Level draft plan view and displacements network on downstream face

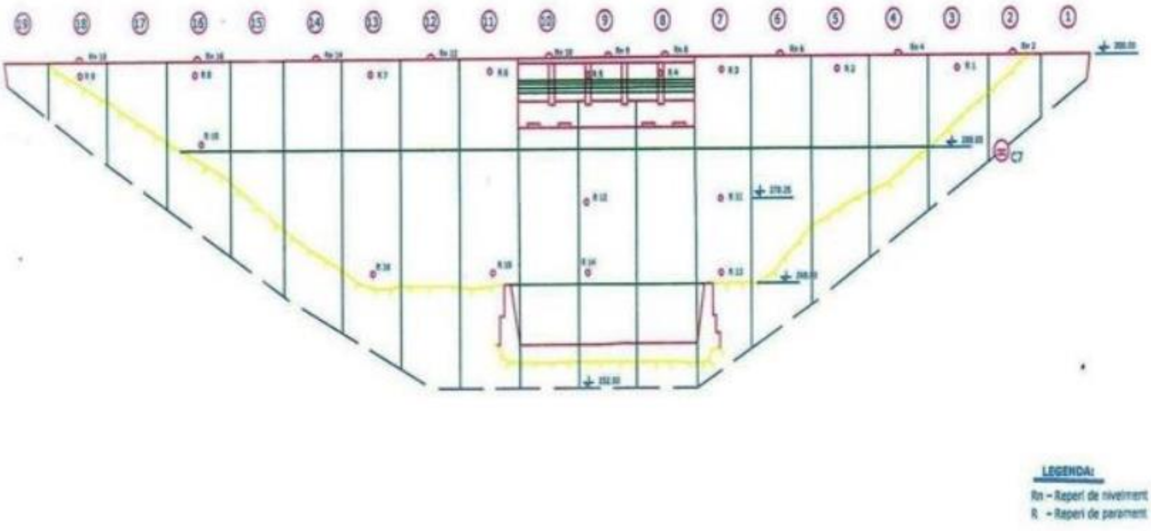


Figure 7. Landmarks' location on the downstream face of the dam

2.3 Dam's vertical displacements monitoring

To track the vertical movements of the dam is geometrically levelled second-order precision, using developed routes through the points of the level network, levelling stops from the crest of the dam, all routes being supported on the fixed landmarks located outside the dam.

The levelling is performed back and forth, closing more polygons. Non-closures on routes of levelling do not exceed the value of 0.2 mm. The accuracy of determining the settlements varies on the length of the levelling route between the fixed points of support. It is used when levelling precision level Invar kit are in use.

The subsidence of the Cinciş dam resulted in the base of the measurements made at the landmarks located on coronation, having the following indications: RC4,RC6, RC8, RC9, RC10, RC12, RC14 and RC16 and their evolution is shown in the figure below:

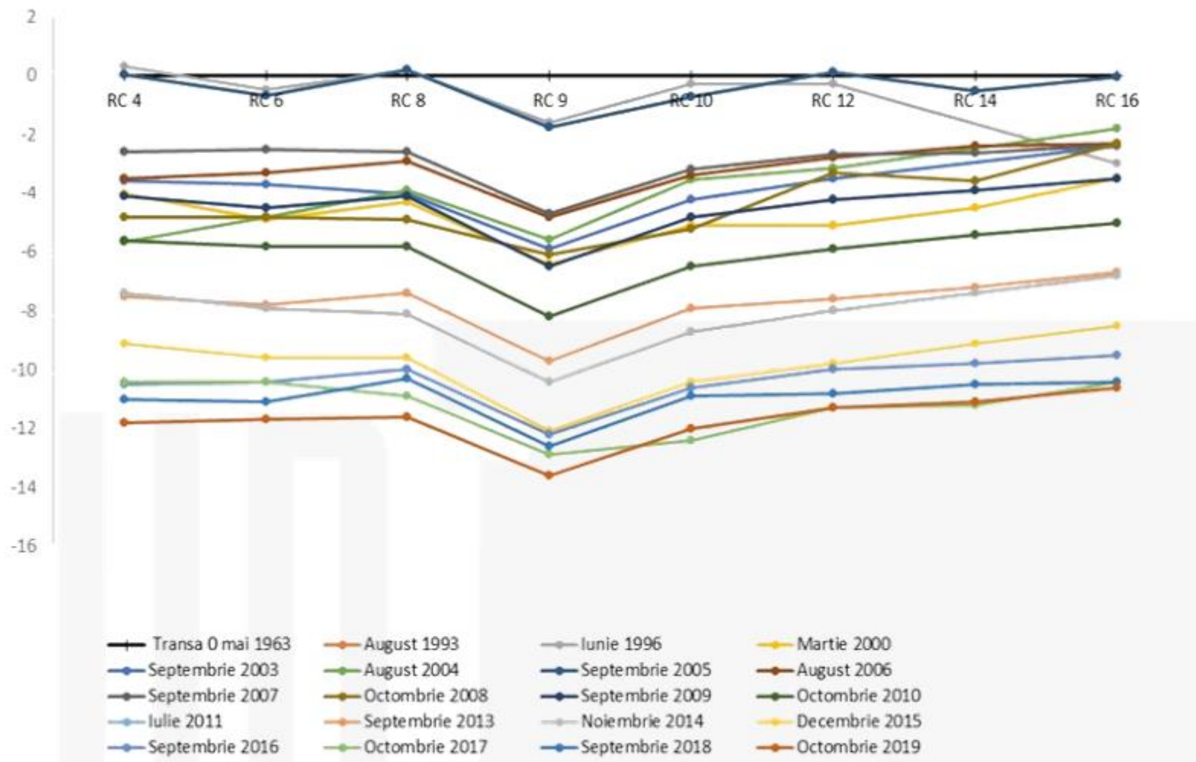


Figure 8. Settlements at crest level

From the analysis and interpretation of the results of the series of levelling measurements, the following emerges conclusions:

- In 2006, the total settlements measured were between 2.35 mm and 4.68 mm, compared to

the year 1963.

- In the tranche of measurements from 2016, the settlements total results of 9.8÷10.6 mm in the right milestones RC4, RC6, RC8, RC10, RC12 and RC14 and of 9.5 mm at the RC16 benchmark, the maximum value of 12.2 mm being measured near the RC9 mark.

Compared to the previous stage, from 2015, the subsidence at the crest of the Cinciş dam had a growth between 0.1÷1.4 mm.

- In the tranche of measurements from the year 2019, the settlements maximum at the crest have values between 10.6÷ 13.6 mm throughout the follow-up period (1989÷2019). The maximum value of settlements at crest is 13.6 mm and was measured at landmark RC9 located in the central area of the dam.

In the period 2006÷2019, the evolution of subsidence occurred with the rate of 0.2÷0.4 mm/year. In the area of the slopes, the subsidence has lower values, between 10.6÷11.8 mm with the annual rate in the period 2006÷2019 between 0.2÷0.4 mm/year.

Compared to the measurements carried out in the 2018 stage, the settlements measured in 2019 evolved with 0÷1.4 mm. The maximum was recorded at the landmark RC4 from the left shoulder of the dam. Were also recorded elevations (swells) in points RC10 of 0.4 mm and in RC14, of 0.1 mm, due probably the influence of temperature.

It is found that the vertical deformations increase in the cold period of the year and there are returns in the summer period. Against this behaviour can consider that the deformations produced are generated by the efforts given by the temperature which are usually characterized by cyclical returns to previously achieved values. On the other hand, the size of these deformations is very reduced and can be entered in the measurement error gap. In conclusion, it can be stated that the dam had, from point of view of vertical displacements, a normal behaviour over time, consistent with the demands to which it was subjected.

3. CONCLUSIONS

For the analysed period, October 2019 – October 2020, the Cinciş Dam behaved normally and may be further exploited, without restriction, in accordance with the Regulations of exploitation.

1. Behavioural parameters have evolved in accordance with the nature and size of shear stresses and are in within the evolution range values.
2. The visual observation did not show elements which could lead to safety reduction or exploitation restrictions.
3. The clogging degree of the reservoir determined following the bathymetric measurements carried out in 2019 is 14.9% at NRL. The flood mitigation role is not affected.
4. The hydromechanical equipment had a normal behaviour during the analyses period. The planned tests were performed. The June 2020 flood transition occurred under normal conditions.

The time behaviour tracking of construction activity organised according with the legal regulations, managed to ensure constructions operation in safe conditions. The operation staff checks monthly the hydromechanical equipment status. All manoeuvres, revisions, breakdowns and repairs are recorded in evidence records. For all automatic equipment installed through Watman project, it is necessary to conclude a service contract with an authorised company, for solving any arise issue while are under operation.

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