VERIFICATION OF TOPOGRAPHIC DRAWING PARAMETERS OF WATER OUTLETS AT EARTH DAMS

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ABSTRACT. *The verification of the topographic parameters at the structural components of the earth dams can be requested within the technical expertises. Actions in the foundation ground or those of a hydrological, hydraulic and seismic nature can influence over time the behaviour of some structural components of the earth dams. The case study prepared through a technical expertise on an earthen dam in the Moldova area highlighted a risk in the operation of the evacuator for high flows. The risk is also generated by a series of topographic features of the longitudinal profile identified by topographic measurements. Risk is also influenced by climate change through the formation of maximum flows not considered in design. The results obtained by the hydraulic simulation of the evacuator confirm a possible faulty behaviour of the connecting channel at the transit of the maximum flows. This situation required the creation of new topographic documentation to verify the construction.*

Keywords: *high flow outlet structure; technical expertise; longitudinal profile; risk*;

1. Introduction

The achievement of the hydrotechnical objectives from the sedimentary rock massifs, respectively to the earth embankments, requires the use of a complex of technical and financial documentation. A set of studies such as topographic, geotechnical, hydrological, hydraulic, climatic, hydrogeological, etc. are used to prepare technical projects. The first of these studies is the topographic one. The elaboration of the technical documentations at various design phases in the hydrotechnical field, respectively the feasibility study, the technical project, execution details, the execution organization project, the construction authorization documentation are based on topographic studies (Popovici, 2020). The management of earth dams is achieved by ensuring a safe operation process, by applying maintenance, repair, rehabilitation and modernization works on time, etc. (Priscu, 1974, Popovici, 2002).

A series of studies conducted over time (ICOLD, 1995, Hobjila et al., 1999, Luca and Hobjila, 2002) have shown multiple degradations in the structural elements of earth dams. These degradations were generated by the random actions present in the site; they appeared during the exploitation period. Many of the negative phenomena were generated by the absence of a correct process for monitoring the operating parameters (Agapie and Luca, 2020, Luca and Pop, 2016, Priscu, 1974). Early detection of faults, defects and anomalies is a very important step in assessing the structural integrity of earth dams and in managing operational risks (Hobjila and Luca, 2000, Seyed-Kolbadi et al., 2020).

Earthquakes are subjected to a complex of deformations caused by factors arising from the design, execution and operation. Deformations occur both in the dam structure and in the site. The weight of the dam, the pressure of the water on the dam and in its body, the tectonic movements, the geotechnical changes of the location are some of the factors that generate deformations at a dam. These factors determine changes in the geometry of the dam through horizontal and vertical structural displacements. Physical changes must be monitored to increase operational safety, efficiency and dam life (Popovici, 2020, Kalkan Y. et al., 2010).

A series of negative behaviours of the components of the dam are generated by the execution mode. Some negative aspects of the dam components can be highlighted at their request when discharging the maximum flows. The structural components of the dam most affected in this case are the outlet structure (unwatering conduit, overflows, high flow discharge channel). Climate change in recent times has contributed to an uneven distribution of rainfall, which has led to an increase in the flow of dams (Agapie and Luca, 2020). This situation requires the analysis of the behaviour of the dam drains at the new values of the sizing and verification flows. These values are also imposed by the modification of the dam design regulations.

In the process of analyzing the surface evacuators of the dams (overflows, drainage channels) it is necessary to check their structural parameters from a geometric point of view. This verification is done by restoring the topographic study, which contributes to obtaining real calculation values (Chirilă et al., 2020, Agapie et al., 2021). In some cases there have been deviations between the projected and executed topographic values of the high water drainage channel (Hobjila et al., 1997). In the current climatic situation, flows can be formed that endanger the proper functioning of the evacuation constructions. Recent studies and research in the area of Moldova confirm the influence of climate change on maximum flows, which together with other negative factors; have contributed to the partial and even total degradation of water drains at dams (Luca and Hobjila, 2002, Dominte et al., 2020).

The current structural and functional condition of many earth dams in categories C and D creates a number of hazards to the natural and human environment through damage and accidents over time. Inspections and technical expertise on the series of earth dams have shown that many of them are not being tracked by an appropriate parameter monitoring program. Lowland dams (category C and D) are very vulnerable to natural and anthropogenic action on site. Accidents are caused by the way of maintenance over time, the absence of rehabilitation and modernization works, but also by the change of the type of property (Luca and Hobjila, 2002).

The paper presents a series of studies and research on the need to verify the topographic data used in the design and execution of evacuators for the maximum flows in the structure of earth dams. The absence of topographic data verification during the expertise of the earth dams may determine the appearance of some risk factors in the operation of the evacuators for maximum flows. The conclusions obtained from the research confirm the validity of this working hypothesis in the expertise of earth dams.

2. Material and research method

The study and research material consists of the technical design documentation of the Chirita Hydrotechnical System. It is located in the south-eastern part of Iasi city (Fig. 1).

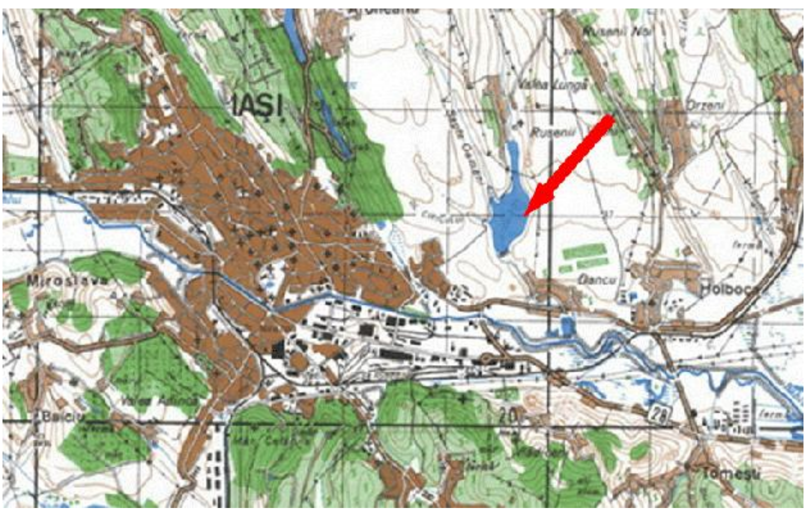

Fig. 1. Location of the Chirita Reservoir (Luca et al., 1999)

Also, the technical documentation included in the technical expertise performed for the Chirita hydrotechnical system was used (Hobjila et al., 1999, Luca et al., 2004, Luca et al., 2009). The topographic documentation for the design of the hydrotechnical system was made in the years 1960 - 1963 by using the existing reference system at that time.

The Chirita hydrotechnical system includes an accumulation lake made of an earth dam and a complex of hydraulic installations with the role of capturing water and diverting it to consumers. The Chirita reservoir is integrated in the water supply system of the city of Iasi. The accumulation lake is fed directly by Long Valley Stream, Seven People Stream (partially) and a volume of water pumped from the Prut River. The accumulation lake has the main role of storing and decanting the pumped waters from the Prut River. The lake is used as a raw water tank by the water supply system of Iasi (Luca et al., 2009).

Long Valley Stream is the penultimate left tributary of the Bahlui River before its confluence with the Jijia River. Long Valley Stream brook has the cadastral code XII - 1.15.32.23. The river basin has the following characteristics: reception area 37 km2 (44 km2 total area); the length of the stream up to the Chirita Valley 13.1 km (16 km total length); average slope 7.67% o (Luca et al., 2009).

The Chirita hydrotechnical system was designed and built in 1962. The Chirita dam is made of local materials taken from the left side of the lake. The main building material was compact loessoid clay. The cross section of the dam is trapezoidal. A berm was made on the downstream facing. The dam has a length of 219 m, a canopy width of 6.0 m and a maximum height of 5.0 m. The upstream facing is protected with concrete slabs measuring 1.0 x 1.0 x 0.15 m. in the area of variation of the exploitation level (Fig. 2.a). At the base of the downstream facing is a filtered mattress made of broken stone (Fig. 2.b). The dam is provided downstream with an infiltrated water drainage system from the lake (Luca et al., 2004).

Fig. 2. General view of the Chirita dam
a - upstream facing; b - downstream facing

The characteristic elevations and geometric parameters of the earth dam are: natural terrain elevation 42.40 m; crown height 54.60 m; concrete slab height = 53.00 m; uphill slope, 1: 3.5 and downstream slope 1.2.5; upstream berm elevation 49.60 m; downstream berm height 49.00 m; crown width 6.00 m; crest dam length = 219.00 m. All elevations are given according to the reference plan at the time of the topographic study.

Chirita Dam is equipped with two constructions for outlet structure water from the lake. The evacuation of the average flows is performed and adjusted at the same time with a control tower and socket connected to a watering conduit. The manoeuvring tower is equipped with cofferdams and water intakes connected to diversion pipes to the consumer (the water supply system of Iasi). The transit of large flood flows, taken over by the accumulation lake, is done with evacuator water. It is a canal type, being located on the right side of the dam and connected downstream to Long Valley Stream (Fig. 3).

The evacuation research method was particularized in the analysis of the situation plans, of the longitudinal and transversal profiles of the evacuators. Topographic measurements were also performed to update

Fig. 3. General view of the location of the outlet structure at the Chiri a dam
1 - the high water discharger; 2 - manoeuvring tower and socket;
3 – unwatering conduit; 4 - sewerage drainage
(Luca et al., 2004, image Google earth, 2010)

the data included in the transverse profile of the high flow evacuator. The topographic tracing parameters of the evacuator were analyzed comparatively for the initial design variant and the existing one at the site.

The hydraulic analysis of the high flow evacuator used calculation programs for specific parameters of permanent and non-permanent flow in free-flowing riverbeds.

3. Results and discussions

For the design of the hydrotechnical complex, a topographic documentation was made, which was used in the design stages: feasibility study, technical design, execution details, approvals and agreements, etc. The topographic documentation was made in 1962.

During the operation of the hydrotechnical system, at predetermined time intervals, a series of technical expertises were performed to verify the state of operation of the structural components. A number of technical expertises were carried out after 1990 by a team of professors from the Technical University „Gh. Asachi ”from Iaşi (Hobjila et al., 1999, Luca et al., 2004, Luca et al., 2009). The expertises were requested from the owner of the Chiri a hydrotechnical system (Apavital Iaşi).

The performance of the technical expertise was also imposed by a series of changes in the legislation governing the hydrological regime of the geographical area of the dam's location, taking into account the climate changes of the last 50 years. Climate change has increased the flow rates, which required the verification of water drains from the dam. Also, a series of updates in the seismic characterization of the Romanian territory required the verification of the operational safety of the structural components of the hydrotechnical system (dam and intake tower) (Hobjila and Luca, 2000, NTLH-022, 2002).

Climate change in the hydrological regime has led to changes in the sizing and verification flows of water drains. One of the requirements of the technical expertise is the hydraulic verification of the dam evacuators when transiting the flows with average and maximum values (Hobjila and Luca, 2000, NTLH-022, 2002). Flow rates with calculation probabilities 1%, 0.1% and 0.01% considered in the hydraulic analysis were: Q1% = 53 m3/s, Q0.1% = 105 m3/s and Q0.01% = 163 m3/s (Luca et al., 2004).

The high flow evacuator has a total length of 325.00 m, of which the connection channel to Long Valley Stream is 61.00 m. The high flow evacuator is a channel with a trapezoidal flow section (Fig. 4).

Fig. 4. General view of the high flow evacuator
1 - access channel; 2 - spillway; 3 - connection channel; 4 - inclined drop zone 1;
5 - inclined drop zone 2; 6 – hydraulic energy dissipater + downstream apron;
7 - escape channel (image Google earth)

The evacuator is composed of the following structural components (Fig. 4): overflow access channel (CA); thick-walled overflow and triangular cross section continued with hydraulic energy dissipater (D + CD1); connection channel (CL) (Fig. 5.a); inclined drop (CR) (Fig. 5.b); hydraulic energy dissipater and downstream apron (D); evacuation channel and connection to Long Valley stream (CE). The channel is made of excavation and is protected by reinforced concrete slabs placed on a filter layer (Fig. 6).

Each structural element is characterized by geometric and hydraulic parameters. Some of the parameters specific to the inclined drop and the connecting channel (Fig. 6) are presented in Table 1.

Parameters from Table 1 have the following definition: b - the width at the screed of the channel; m - the angular coefficient of the slope; n - roughness coefficient (Manning); i - geodetic slope; Lc - calculation length.

Fig. 5. The state of the flow section of the high flow evacuator
a - connection channel (CL); b - inclined drop (CR1) (Luca et al., 2009).

Table 1. Structural parameters for hydraulically analyzed channel sections

Channel	b (m)	m	n	i	L_c (m)
CL	3.00	1:1.50	0.013-0.015	0.005	87.00
CR1	3.00	1:1.50	0.013-0.015	0.10	50.50
CR2	3.00	1:1.50	0.015	0.10	40.00

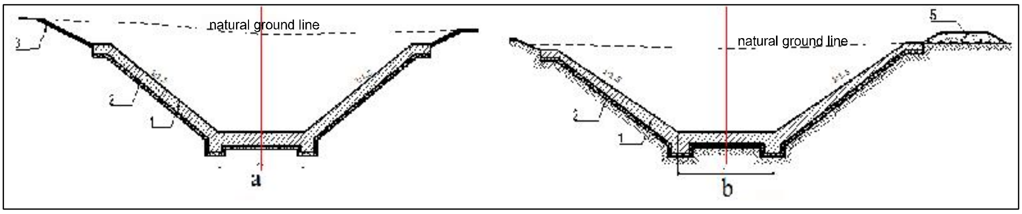

Fig. 6. Cross sections: a - connection channel (CL); b - inclined drop (CR1), 1 - concrete slabs, 2 - ballast layer, 3 - grassy slope, 4 - natural ground, 5 - embankment (Luca et al., 2004)

The hydraulic verification of the canal followed the determination of the parameters that intervene in the transit of the maximum flows taken over by the evacuator. The parameters tested were as follows:

- water height: variable (h), normal (h0), critical (hcr) control (hc);
- water speeds: average (v), maximum (vmax);
- state of motion (SM) on the channel section using the Froude number (Fr) and the critical slope (icr);
- the length of the curves of the free surface on each section (LCS);
- connection scheme of the canal diversions.

The hydraulic-mathematical model was formed by the equations of motion of the water of the permanent non-uniform type gradually varied. The main equations used in hydraulic analysis were (Luca, 1998):

- equation of gradually varying permanent motion:

$$\frac{dh}{dl} = \frac{1-\frac{Q^2}{A^2C^2R}}{1-\frac{\propto Q^2}{g}\frac{B}{A^3}} \qquad (1)$$

- the equation of permanent motion:

$$Q = AC\sqrt{Ri} \qquad (2)$$

- the equation of the Froude number and the critical slope, etc .:

$$Fr = \frac{\propto v^2}{gh} = \frac{\propto Q^2 B}{gA^3} \quad (3) \qquad i_{cr} = \frac{Q^2}{K_{cr}^2} \quad (4)$$

where Q is the computational flow rate; A - air; R - hydraulic radius; C - Chézy coefficient; K flow mode; h - water depth; B - the width of the water gloss; icr - critical slope.

The hydraulic calculation was performed with a computer program made in the Matlab programming field. The analysis of the longitudinal profile designed for the evacuator (Fig. 7) shows for the connecting channel a slope of the eraser of 0.5%. In general, this section is designed with a slope that determines a state of subcritical movement when transiting sizing and verification flows. The hydraulic analysis was performed in three scenarios differentiated by the value of the calculation flow. The results obtained are summarized in Table 2.

A special problem in the calculation was given by the definition of the roughness coefficient of the channel on each section. The climatic action on the canal over a long period of time caused the degradation of the surface of the concrete slabs by the erosion of the protective plaster. Also, a series of tiles have cracks and fissures. The joint made of cement mortar between the tiles was degraded and expelled. In this situation, the scenarios for the projected variant (n = 0.014) and the variant at the time of the expertise (n = 0.015) were analyzed (Luca, et al., 2004).

The hydraulic analysis performed indicated the presence of a supercritical motion regime in the three scenarios considered in the research on this section. The value of the normal water depth on each section is greater than the corresponding critical depth; in this case a supercritical state of motion results.

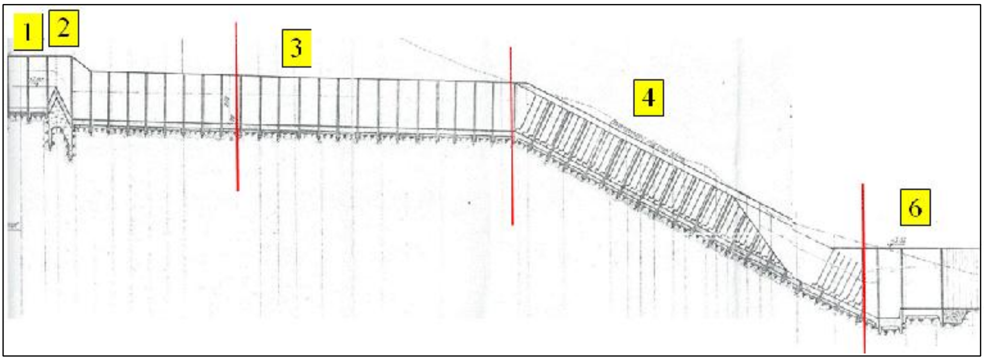

Fig. 7. Longitudinal profile through the high flow evacuator (Luca et al., 2004)

Table 2. Results regarding the hydraulic analysis of the connecting channel

No.	Q (m³/s)	h_0 (m)	h_{cr} (m)	v (m/s)	Fr	SM
1	$Q_{1\%} = 53$ m³/s	1.774	2.218	5.278	1.677	supercritical
2	$Q_{0,1\%} - 105$ m³/s	2.479	3.128	6.305	1.716	supercritical
3	$Q_{0,01\%} - 163$ m³/s	3.050	3.870	7.055	1.680	supercritical
Trapezoidal section, m – 1:5, i – 0,005, n – 0,014, L_c – 87,0 m						

Also, the supraunitary values of the Froude numbers in each scenario confirm the presence of a supercritical state of motion.

The comparative analysis of the velocities obtained in the three scenarios with the maximum allowed value (erosion rate for the concrete class used in the execution of the slabs) shows that the concrete slabs will be eroded by the action of water. For a C6 / 7.5 concrete classes, a maximum water speed of 3.8 - 4.40 m/s is allowed (Luca, 1998). If we take into account the long service life, where the action of meteorological factors has contributed to the degradation of concrete, it turns out that the tiles will be eroded by high water speeds.

After performing the hydraulic analyzes and interpreting the results from 2004, it was considered necessary a new topographic survey of the components of the hydrotechnical system considering the long period of operation (about 42 years) (Luca et al., 2004). At the same time, the geodetic reference base for the preparation of topographic documentation was changed (Fig. 8).

For the earth dam and its annexes (manoeuvring tower and socket, high flow evacuator) a new topographic documentation was made. The topographic measurements were performed plan metrically in STEREOGRAPHIC-1970 projection system and altimetrically in elevation system BLACK SEA 1975. The geodetic lifting network was made with the help of points from the geodetic support network in the area of Lake Chirita. For the study area, a circuit trip was performed using a total LEICA TCR 407power station. Non-closing errors on guidelines and coordinates were within the tolerances allowed. The points of detail were determined by the method of erasure from the points of the geodetic lifting network using the total station. The new points were materialized on the field by metal pegs and wooden logs painted in red. Field observations were made in conditions of optimal visibility and calm atmosphere.

The situation plans were drawn up at the specific scales of the hydrotechnical water management system (1: 1000, 1: 500, 1: 200). For the high flow evacuator and the crowning of the dam, longitudinal profiles and cross sections were made at the stairs indicated by the design regulations.

The comparative analysis of the topographic documentations confirmed the initial geometric parameters of the channel sections that form the high flow evacuator. At the same time, the new topographic documentation updated the topographic parameters of the dam, the manoeuvring tower and the water drains Fig. 8. Situation plan of the water evacuators at Chirita Dam (Luca, et al., 2009) according to the currently used geodetic base.

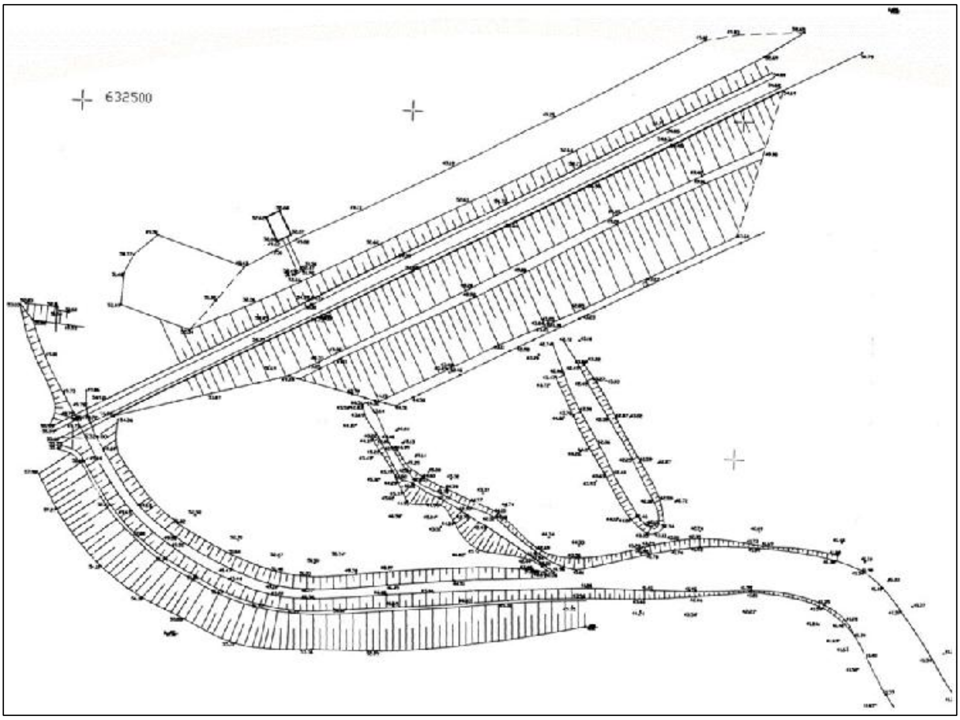

Fig. 8. Situation plan of the water evacuators at Chirita Dam (Luca, et al., 2009)

Research and studies on the potential behaviour of the high flow evacuator with partially degraded structural condition, at flood flows with the considered calculation probabilities, indicate a state of supercritical motion on the connecting channel. This state of motion, as well as the formation of high value water flow velocities (v = 6...7 m/s), can trigger erosion phenomena and instability of the tile protection.

The entry of water from the connecting channel on the fast channel with a much too high speed can cause intense erosion phenomena of the construction. The degradation situations of the water discharges presented in the research carried out on the dams in the river basin of the Prut River confirm the presence of the phenomena of exceeding the projected values and erosion rates (Dominte et al., 2021. Also, research carried out in the last period of time require monitoring of dams by modern methods (Kalkan, 2009, Levent, 2008, Agapie et al., 2020, Vele et al., 2014, Zhang et al., 2018) Some deficiencies can be removed by rehabilitation works of the protection of the high flow discharge channel.

4. Conclusions

1. The topographic documentation is a main component in the elaboration of the technical projects for the execution of the hydrotechnical works of water management, respectively of the dams for accumulations, and its updating is imposed by the changes in time of the geometry of the constructions in time.

2. Geometric parameters that characterize the structural components of earth dams are modified over time by the actions in the location environment, a situation that requires the continuous adaptation of topographic studies at certain intervals.

3. The updating of the topographic documentation can be done in the exploitation phases of the water drains from the earth dams to complete the situation plans, the longitudinal and transversal profiles with details that take into account the changes generated by the execution process and the construction exploitation mode.

4. The updating of the topographic documentation is necessary in the current operation phase of the high-flow discharges at the earth dams, taking into account the

influence of climate change on the hydrological regime of the rivers and the substantial increase of flood flows.

5. The updating of the topographic documentation is necessary in the technical expertise phase of the high flow outlet structure at the earth dams, in order to correlate the parameters presented in the execution plans with the existing situation in the field after a relatively long period of operation.

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