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Policy and Improper Management of the Dams realized by Local Materials with Possible Risk in Exploitation

Victorita RADULESCU*

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Policy and Improper Management of the Dams realized by Local Materials with Possible Risk in Exploitation

Victorita RADULESCU[1]*

Abstract

The present paper presents a study case of improper rehabilitation and inefficient management of the water volume from two hydropower lakes, with dams realized by local materials. Romania has hydraulic potential, water being one of the most available resources. Realization of dams by local materials represents one of the most economic and efficient solutions, well used at large scale in Romania during '80. In this article is presented a study-case with two dams improperly executed and maintained. Nowadays, local authorities are confronted with infiltration and erosion appeared into both lateral sides of the dikes. The article structured into seven parts intends to cover some theoretical and practical aspects referring to the exploitation and modeling of the appeared problems. The dam execution was not correlated with the local geographic conditions, climatic parameters, soils and water characteristics, but mainly with the basic geologic considerations. The numerical model was calibrated based on these observations. Some mathematical aspects, based on three theoretical models of infiltration through materials with different shapes, characteristics, and dimensions are scheduled. The flow through cross-sections is a permanent flow, due to constant infiltration. Some obtained results for infiltration velocities and streamlines are illustrated. Several proposed and tested solutions to reduce the erosion and infiltration and to optimize the management of the lake are mentioned in sixth part. The conducted study is a request of local authorities, in order to improve the performance of these hydropower lakes. Finally, the paper ends with some discussions, conclusions, and references.

Keywords: Water management, Soils particle size, Hydrographical network, Groundwater flows, Numerical modelling.

1. Introduction

[1] University Politehnica Bucharest, Romania, e-mail address: vradul4@gmail.com

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Corresponding Author: Victorita RADULESCU
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The Cris basin drains an area of over 27.500 km^2 of land, which consists of four major rivers that converge like branches of a tree: Crisul Alb, Crisul Negru, Crisul Repede and Barcau. The analyzed dams, confronted with infiltration problems are realized on river Crisul Repede on the western slopes of the Apuseni Mountains. The distribution, the flow regime for the rivers from the basin Cris are conditioned by the physical-geographical natural of the unit they cross, the terrain, the morphological structure of the sediments and of the main composition of the dam structure. The Apuseni Mountains, where the lakes were built, are distinguished by a greater amount of rainfall compared to other regions with similar altitudes in Romania, due to the west exposure; here it falls water over 1400mm/annually. At the international level, there is a constant policy in promoting and utilization of renewable resources. From the investigations made in the last 3 years, the higher specific annual average leak of water is in the mountains and hills region. Here are the analyzed lakes because it can reach 30-35 $l/s/km^2$, due to the mentioned amount of rainfall, to the sharp slopes of drain zone and due to the petrography substrate generally impermeable. It was selected two lakes, at local authority suggestion, as to find possible solutions at to the appeared problems. Over the years, are necessary a series of hydraulic works on both main courses as to restore the damages produced, especially after the floods registered in 1998.

The level of the free surface in these two cascade lakes reduces by 7m and 9m respectively, with immediate effect of diminishing the amount of water, representing energy losses. Under these circumstances, the lakes aren't able to take the excess of water appeared during floods occurring in 1999, 2000, 2001, 2002, 2005, 2008, and 2012 (2005, 2008- massive floods).

At the international level, the problem of infiltration through dams and dikes represent one of the actual issues since in Egypt, in 2003, at Kashkan dam was registered a similar problem. In that case, the infiltration through dam was so high that it was necessary to complete emptying the lake and rehabilitate the dam. In the last 5-6 years, especially after the floods registered in 2005 and 2008, were recorded occurrences of erosion of the both shores followed by massive displacements of the concrete slabs in the form of craters, followed by collapses of the sidewalls. It is necessary to find a solution as to restore with the minimum investment, materials, and especially in short time the affected areas.

The mathematical model was structured and based mainly on local data collected in situ, referring to hydrological capacities, average values of rainfall, type, nature, and dimensions of sediments, infiltration from the favourable area. The results were compared with the existent data and completed with old values measured during the time, since the dam' construction. Based on this, a completed database is accomplished and the numerical model was tested. There were determined the current lines and the flow rates of the water of infiltration and were determined the high-risk areas of erosions. The model solves this problem and determines as accurately as possible (taking into account that the lakes area has near several towns and cities) the erosion problem. Taking account of the urgency of the problem, some cross sections with high-risk in exploitation, now in operation, must be rebuilt are presented. There are also mentioned some recommendations and proposals for lake rehabilitation.

2. Problem statement, elaboration of the experimental data-base

The maximum flow rate with insurance 1% can be achieved in Oradea on Crisul Repede, at 970 m^3/s and the minimum value, with insurance of 80% in the period of April-November at 1.60 m^3/s. In Table 1, the registered data are presented.

Table 1. Water flow rate required to be transport through the lakes

Hydro station	Main Flow rate (m^3/s)	Minimum Flow rate (m^3/s)	Maximum Flow rate (m^3/s)
Vadu Crisului	19,60	0,71/24.11.1972	780/04.2005
Oradea	23,10	0,81/19.12.1953	820/04.1932

The annual average flow of alluvial deposits in the suspension is 3.5 kg/s in the post Salard, of 7.5 kg/s in Oradea and 6 kg/s in Zerind post. The specific annual average leakage of silt in the suspension is below 0.5 tons/ha /year in the flat regions and between 0.5 and 1 t/ha/year in the hills and mountains with low altitudes. Higher values of leakage in hillside areas can be explained by the presence of a petrography layer easier to be eroded.

Further are mentioned the most important climatic data and the main characteristic of lake utilization, Table 2.

Climatic data:

Average annual precipitation

- Mountain area - 1600 mm/year
- Hill area - 550-600 mm/year

Average temperature

- Mountain area – 4^0 C
- Hill area + 10^0 C

Table 2. Lakes conditions

Lakes	Volume (mil. m^3)	Used flow (m^3/s)	Discharged Flow (m^3/s)	Bottom drain
Lake 1	33768	12,3	0,1	2
Lake 2	44039	10,1	0,14	2

3. Theoretical and practical aspects of the research

During measurements made in several times in a different period of the year in 2006-2008 in both lakes was structured a chemical composition of water, due geo-morphological land structure but also taking into account the human activities. The results are presented in Table 3.

Table 3. The chemical composition of the water from lakes

Place/Parameter	Bologa	Ciucea	Cheresig
Phosphate (mg/l)	0,48	0,08	0,35
Bicarbonate (mg/l)	390	255	125
anionic detergents (mg/l)	0,18	0,02	0,01
Cr (mg/kg) in sediments	13	8	23
Copper (mg/kg) in sediments	16	10	18
Dissolved Oxygen (mg/l)	10	8,5	2
Ammonia (mg/l)	0,02	0,04	0,23
Ammonia nitrogen (mg/l)	0,09	0,08	0,4
Copper (mg/l)	4,2	1,1	1,3
Lead (mg/l)	0,6	0,25	0,7
Cr (mg/l)	1,25	0,3	1

The quality of surface water quality is regulated by STAS 4706-74 and STAS 9450-98 with some amendments made in 2008. In MAPPM order nr. 756/1997 it was determined for the surface and underground water, the intervention thresholds at levels exceeding the maximum permissible concentrations for a number of pollutants. As the main polluters of surface waters were considered the wastewater generated by various human activities and were regulated the maximum permissible values.

The measured values made by the Water Authority "Cris" and by the Environmental Protection Inspectorate Bihor in monitoring stations the registered values were within the values laid down by law. Consequently, the development works of the river finished by the construction of seven hydropower systems with an installed power of 208 MW, 5 dams, and over 34 km of main and secondary headrace.

Two lakes were confronted with plenty infiltration, since the beginning of the commissioning, Fig.1 a, b.

Figure 1-a,b. Infiltration through dams

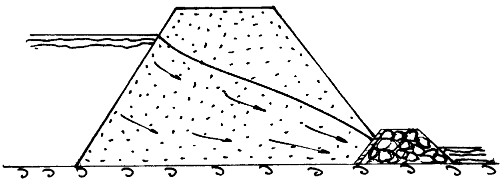
Both photos, mentioned in Figure 1 are made during the first campaign of measurements, by a team of researchers from University Politehnica of Bucharest, coordinator Prof. PhD. Eng. Victorita Radulescu, and from Hidroelectrica SA, the local authority.

4. Mathematical model

Schematically, the problem of infiltration through dams is presented in Figure 2. One of the most important parameters in seepage analysis is the porosity of the material found in the dam structure and lack of the sealing systems and the presence or absence of protection screens.

By introducing the infiltration flow rate Q of the entire water current and the real cross section [1], it may be estimated the average speed ω of infiltration. Imposing a permanent flow through dams and taking into account of the variation of the permeability, it was determined the necessary conditions to establish the form of the streamlines.

Figure 2. The model of infiltration through dams



The theoretical estimation is different from the real one, measured in-situ. If from the entire area of the filter we consider the real pores, the velocity V' becomes greater than the theoretical one-ω due to the huge variation of the structure of the dams material and partially of the presence of some small protection screens. This is the first reason why even from the moment of designing and the execution of the dams, the local authorities confront with infiltration impossible to drain.

The equation corresponds to a surface of infiltration [2], having portions in the shape of a parabola of second degree; the appearance of the variation of water flow followed by the seepage between the bedrock waterproof and the areas with different porosities and permeability is analyzed, based on the assumptions made by Hazen, Kozeny, and E.A. Zamarin [7]. The infiltration coefficient [3] was determined in three ways:

- by theoretical relations
- by measurements 'in situ'
- by experimental laboratory testing on samples [4]

Finally, it is selected a medium value, based mainly on collected samples. In practical applications are frequent the cases when the groundwater current has a large width so it can be considered, in portions, a rectangular cross-section [5], and consequently, the problem may be considered practically plane. In fact, many discrepancies have the immediate effect a modification of the streamlines in the cross-sections and variation of the infiltration velocity. This is the second reason why the real infiltration is higher than the initially estimated.

5. Numerical results

It was modelled the seepage through embankments on the right side and on the left side. Consequently, for each studied case, under the previous considerations, are set three levels of the water in the lake and permeability coefficients, based on local measurements.

The cross sections considered at risk in the transport of the tributary flows are selected from the sections mentioned in Table 4.

The rate flows considered:

- the attention of the river flow Q=290 m^3/s;
- flood flow, Q=472 m^3/s;
- the flow of danger: 567 m^3/s

From the numerical modelling was observed that the downstream shore is discontinuous, consisting of fine sand, medium rare gravel, sandy clay loam sands-profit, lens mud and vegetal elements.

The material structure is bedrock with alternate marl, clay marl, and tuff fine sands.

Table 4. The analyzed sections and their length

Section type	Length on top	Up stream	Down stream	Applied length [m] Left/Right size	
15m < H < 27m	6,00	0,48	0,08	2627	1827
7.5m < H <15m	6,00	390	255	2700	3600
2.5m< H <7.5m	4,00	0,18	0,02	1850	1050
H < 2.5	4,00	13	8	890	546
			Total length	8067	7023

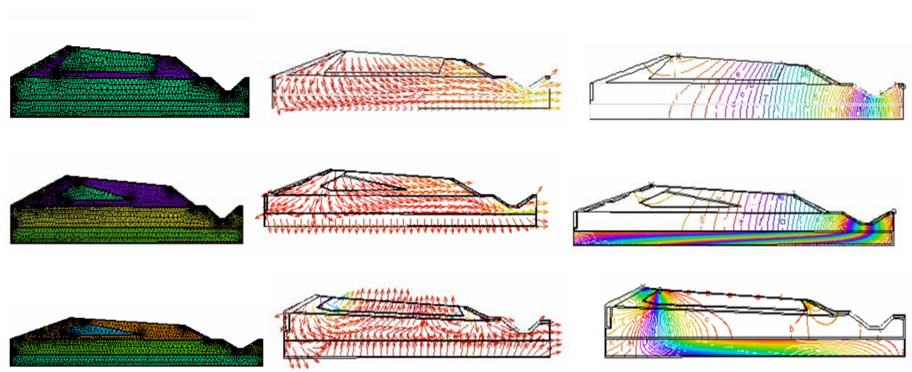
The program performs automatic the distribution of the finite element. Consequently, are represented the streamlines and the infiltration velocities. Depending on the values of the flow rates recorded for each section, for each analyzed case can be determined the risk zones of the entrainment of the fine materials and so the occurrence of the erosion [6].

Furthermore, are presented some numerical results, Figure 3 with different dam structures, different finite element mesh, velocity distribution, the streamlines variation:

Variant A-area with the continuous screen until the bedrock,

Variants B, C, D – with sections with different values of the water level infiltration, depending on the local porosity of the dikes material in the cross-sections and the position of the base bedrock, where there is no infiltrations.

Figure 3. Numerical results, Variant A, B, C, D



6. Discussions

In Table 5 are mentioned the areas where the seepage was observed, in conformity with the results obtained with the numerical model.

Table 5. Areas with the observed seepages

Left dam bank						Right dam bank					
Developing area	B	C	R	T	G	Developing area	B	C	R	T	G
Profile						Profile					
300.5- 300.6				x		410.0- 413.0	x	x	x		
303.1-303.4			x	X	x	416.7-417.0	x	x	x		
303.8- 303.9			x	X	x	429.0- 430.0	x	x			
303.0- 304.0				X		434.0- 435.5	x				
303.6- 304.5			x		x	437.5- 437.9	x	x	x		
307.1- 307.3	x	x			x	438.5- 439.5	x	x	x		
307.5- 307.9	x				x	439.0- 446.3	x	x			
308.0- 308.2	x					445.0- 445.9	x	x	x		
356.0- 356.2	x	x				458.0- 460.0	x	x			

Where: B-puddles on bank, C–wet bank, R– wet upper side of dam, T– wet lower side, G – ice, x – reported issue, X – more intense phenomena

The obtained results confirm the validity of the elaborated numerical model. The provided seals to rehabilitate the dike are as follows:

- for the foundation: screen gel sealing of concrete or concrete placed at the foot of the upstream executed excavation, on an average depth of 5.00 m and an average thickness of about 0.70 m, with embedding in the bedrock;

- the dam body: reinforced concrete mask applied to the upstream face with 20 cm thick in the areas where the retention height exceeds 5 m and thickness of 15 cm for the areas where the height of the retention is between 2.5 m and 7.5 m

The joints are sealed with the mask of PVC tape and mastic azbobituminos. Contact between screens is made by sealing with the local sediments and the mask sealing was done through a reinforced concrete beams fitted with PVC sealing tape.

In 2008 when it was necessary to be discharged a large amount of water to avoid flooding due previous erosions appeared more infiltration areas, as it is presented in Figure 4-a followed by cracks in the side walls of the concrete Fig.4-b. In a short time appeared craters having 1- 2 m in diameter. Both photos, mentioned in Figure 4 are made during the second campaign of measurements.

Figure 4. Massive infiltration and cracks of the concrete

7. Conclusions

Nowadays the utilization of renewable resources represents one of the main objectives of the international scientific community. The water utilization represents one of the most attractive resources of electric energy production. In 2003, a major environmental problem appeared in Egypt; unfortunately in Romania are in present two hydropower lakes, with similar problems, need to be solved as quickly as possible. Consequently, the analyzed zone confront with massive infiltration through the both sides of the channel. As to establish the most affected areas was realized a numerical model for simulation of the flow rate of infiltration through the cross-sections, the water velocities as to estimate where there is a risk of further erosions. It was performed a mesh for each cross-section, depending on specific permeability material (bedrock, filter material, screen, etc.). Each field is different coloured. Since the commissioning of the dam, the level of the free water due improper execution rests at low values. The deficiencies appear mainly in the conditions of managing high flow rate of water during floods. There were conducted technical and economic documents enabling to identify zones where the concrete do not meet the conditions of the technical specifications. Now, both hydropower lakes currently work with reduced levels of water than in normal conditions, allowing less electrical energy to be produced. Both lakes are maintained in permanent attention-alert. By performing the recommendations, it is possible to establish new working conditions, safer for the local community, taking into account that in near vicinity of hydropower lakes are many localities and cities.

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