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CONSIDERATIONS REGARDING THE LEVEL OF INFILTRATIONS AT AN EARTH DAM WITH A DRAINAGE MAT
CASE STUDY: MILEANCA DAM

BY

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Abstract. In recent years, Romania has been showing special interest in equipping dams with measuring and control instruments, able to read the measured parameters automatically. One of the phenomena that manifests interest to be measured automatically is water infiltration through an earth dam. The main issue of interest is the comparison between automatic calibration readings and theoretical calculation of the infiltration curve through an earth dam. In this paper, it was tried such a comparison for an earth dam having a drainage mat.

Keywords: infiltration curve; earth dam; drainage mat.

1. Introduction

Mileanca dam is realised of homogeneous soil, disposed with a drainage mat at the downstream slope and was opened in 1971. It is located on the River

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Podriga, cadastral code XIII.1.010.06.00, near Mileanca, in Botoşani County. The dam is made of local materials, predominantly yellow silty clay, whose geotechnical characteristics are: g = 2.0 t/m^3, filtration coefficient $k = 10^{-6}$ cm/s, F = 150, C = 0.2 kg /m^2.

The geometrical characteristics of the dam are:

a) the length of front sealing is 458 m;

b) the crest elevation is 128.08 mdMN;

c) the crest width is 5 m;

d) the slope of the upstream bank is 1:3.5;

e) the slope of the downstream bank is 1:3;

f) the maximum height of the dam is 10.08 m.

Between 2008 and 2012, "Securing Mileanca accumulation on the river Podriga, Botoşani County" project was achieved. Thus, there were planned and executed, mainly, the following works:

1º Reshaping the dam.

2º Restoring existing tile pitching, on certain parts.

3º Rehabilitation of the spillway, total restoring of the energy disperser and of the downstream apron of the surface discharger.

4º Setting up a sealing screen, made of self-hardening clay at the dam upstream toe.

5º Setting the drainage system for the left side and rehabilitation of drainage downstream of the dam.

6º Rehabilitation of hydro-mechanical equipment, tower maneuver and bottom emptying.

7º Disposal of new piezometric wells in four measuring sections (Fig. 1).

8º Implementation of an automatic system of monitoring and alarming.

After rehabilitation and modernization, the dam was reinstated in 2012 under load.

For the calculation of the infiltration curve the aim was to compare theoretical infiltration curve, obtained by calculation, with the one obtained using the measurements from the piezometric wells. There are 12 wells in the Mileanca dam arranged in 4 measuring sections. According to the drilling reports, the wells have the following depths:

Section 1: P1 = 4.00 m, P2 = 6.40 m, P3 = 9.00 m;
Section 2: P4 = 2.60 m, P5 = 5.50 m, P6 = 9.00 m;
Section 3: P7 = 3.00 m, P8 = 6.30 m, P9 = 9.40 m;
Section 4: P10 = 3.55 m, P11 = 6.30 m, P12 = 9.30 m.

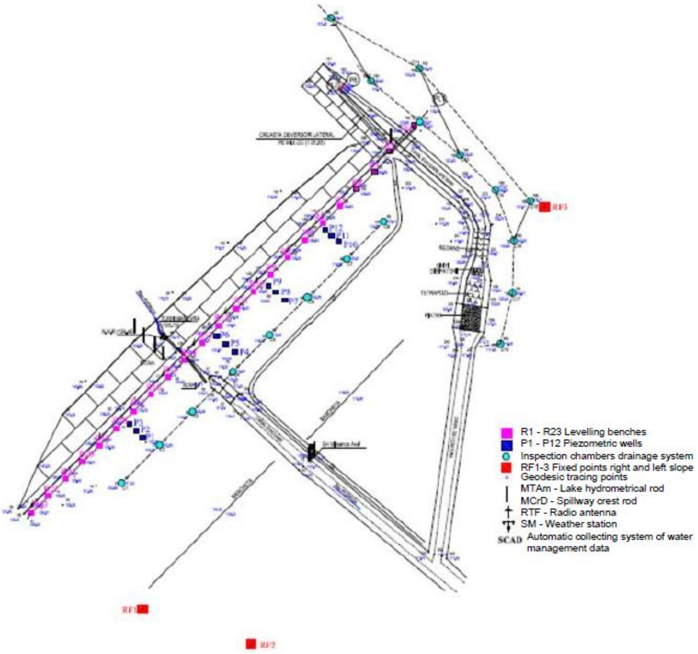

Fig. 1 − Disposal of piezometric wells on Mileanca dam.

2. The Theoretical Calculation of the Infiltration Curve for a Dam Made of Homogenous Material, Disposed with a Drainage Mat

In common engineering practice, the calculation of the infiltration through an earth dam with a drainage mat can be realised by using "Numerov" method, described in the paper "Calculation of infiltrations" (Figs. 2,...,4).

The free surface of the infiltrated water can be calculated using Numerov formula.

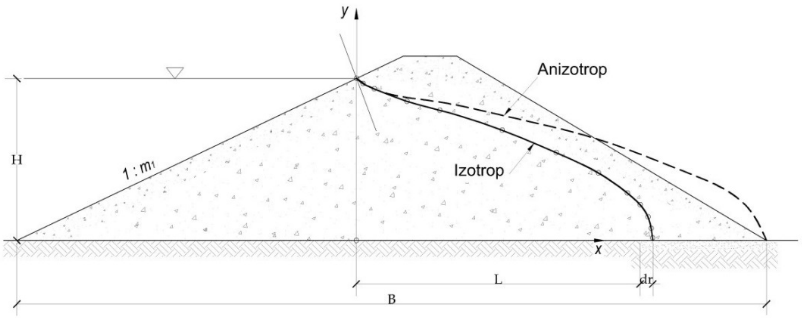

Fig. 2 − Calculation scheme of the infiltration curve through an homogenous earth dam with a drainage mat.

$$x=\frac{H^2-y^2}{2\frac{q}{k}}-HF_1+\frac{q}{k}F_2, \tag{1}$$

where:

$$\frac{q}{k}=\frac{H^2}{L+Hf_1+\sqrt{(L+Hf_1)^2+H^2f_2}},$$

and x and y are the coordinates of the free surface curve (y = 0...H); H – water calculation level; F_1 and F_2 are functions of two arguments: m_1 and s:

$$s=\mathrm{th}\frac{\pi(H-y)}{2\frac{q}{k}}.$$

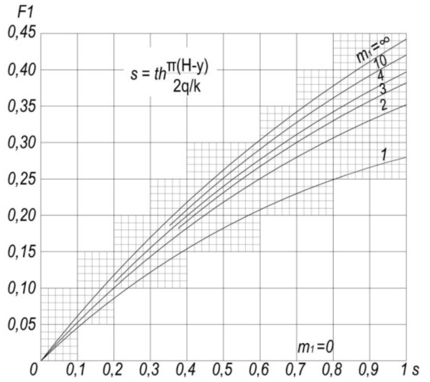

Fig. 3 − Calculation diagram of F_1 function using Numerov.

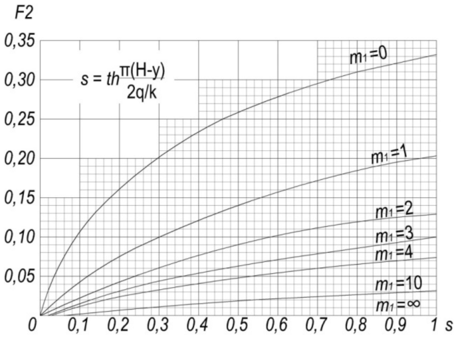

Fig. 4 − Calculation diagram of F_2 function using Numerov.

f_1 and f_2 coefficients are based on the upstream slope and are chosen according to Table 1.

Table 1

f_1 and f_2 Coefficients

m	0	1	2	2.5	3	4	5	6	8	10
f1	0.00	0.28	0.35	0.37	0.38	0.40	0.41	0.41	0.42	0.42
f2	0.33	0.69	0.73	0.77	0.80	0.85	0.87	0.89	0.92	0.93

3. Application of Theoretical Calculation for the Mileanca Earth Dam (Homogeneous, with Draining Mat)

Regarding the data presented above, the calculation of the infiltration curve was performed in "theoretical" version using the "Numerov" method. Calculation results achieved in "Excel" are presented as spreadsheets and graphics below (Tables 2 and 3).

Table 2

The Input Data for the Program and the Obtained Infiltration Discharge

		q/*k*
H	6.33	0.499
L	37.46	
f_1	0.39	
f_2	0.825	

Table 3

The Coordinates x and y of the Infiltration Curve Using Numerov Method

y	F_1	F_2	*s*	*x* (relative)	*X* (general)
6.33	0	0	0	0	22.15
6	0.39	0.09	0.777254	3.340499	25.4905
5.5	0.39	0.09	0.98928	9.099929	31.24993
5	0.39	0.09	0.999537	14.35854	36.50854
4.5	0.39	0.09	0.99998	19.11633	41.26633
4	0.39	0.09	0.999999	23.3733	45.5233
3.5	0.39	0.09	1	27.12945	49.27945
3	0.39	0.09	1	30.38478	52.53478
2.75	0.39	0.09	1	31.82464	53.97464
2.5	0.39	0.09	1	33.13929	55.28929
2.25	0.39	0.09	1	34.32874	56.47874
2	0.39	0.09	1	35.39298	57.54298
1.75	0.39	0.09	1	36.33202	58.48202
1.5	0.39	0.09	1	37.14585	59.29585
1.25	0.39	0.09	1	37.83448	59.98448
1	0.39	0.09	1	38.3979	60.5479
0.75	0.39	0.09	1	38.83612	60.98612
0.5	0.39	0.09	1	39.14913	61.29913
0.25	0.39	0.09	1	39.33694	61.48694
0	0.39	0.09	1	39.39954	61.54954

After the completion of the calculation done in Excel, it resulted a theoretical infiltration curve whose graphical representation is shown below (Fig. 5).

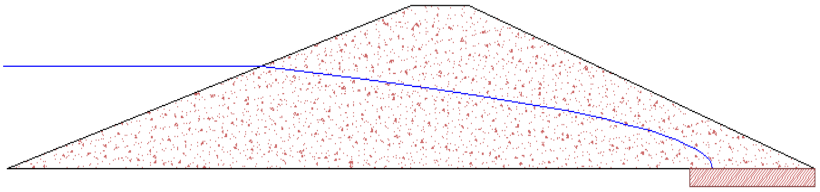

Fig. 5 – Theoretical infiltration curve in Mileanca dam.

4. Data Regarding the Infiltration Through Mileanca Dam, Obtainted by Actual Measurements

By processing the measurements done in the piezometric wells arranged in the 4 cross sections and the study of the evolution of the water levels from them, there were obtained data indicating the maximum and minimum values, maximum increases and decreases.

Depression curves taken at the maximum level in the lake, respectively 124.24 mdMN (08/05/2013), delimit small areas of the dam, and they discharge at the bank downstream foot in the drainage system, consisting of the drainage mat and collector drain Dn = 300 mm.

It was managed to obtain a set of values related to the water level in Mileanca dam piezometers, for a period between August 2013 and July 2015, for each of the 12 piezometric wells (Figs. 6,...,17).

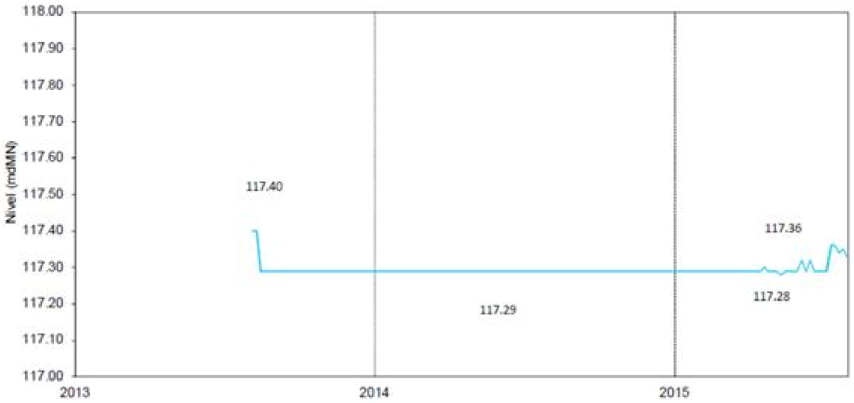

Fig. 6 – Water level variation in P_1 piezometric well.

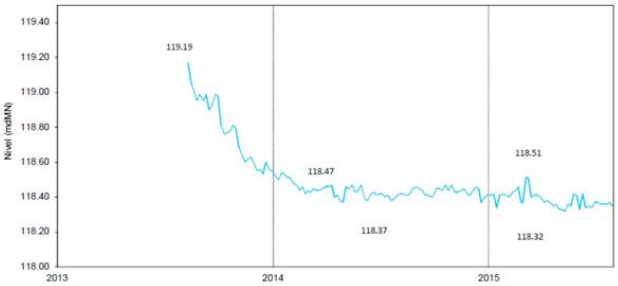

Fig. 7 − Water level variation in P2 piezometric well.

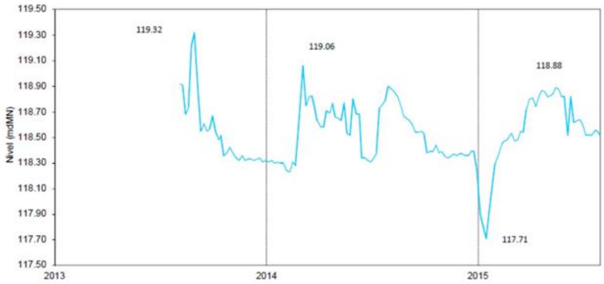

Fig. 8 − Water level variation in P_3 piezometric well.

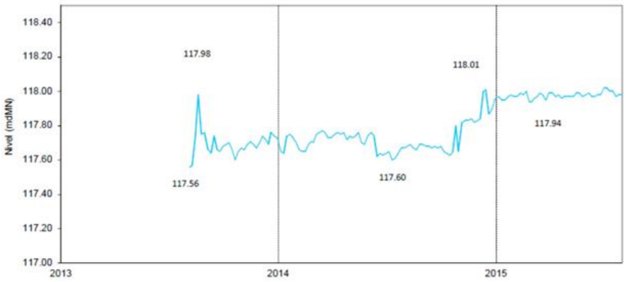

Fig. 9 − Water level variation in P4 piezometric well.

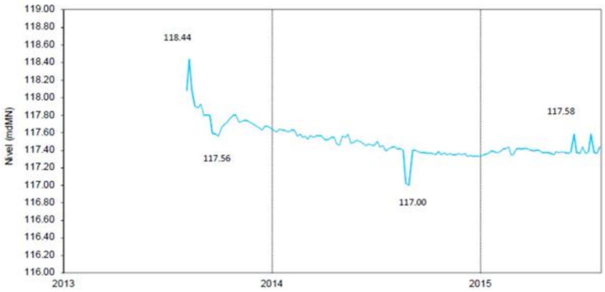

Fig. 10 − Water level variation in P_5 piezometric well.

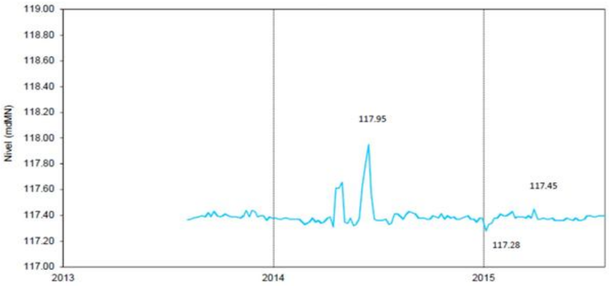

Fig. 11 − Water level variation in P_6 piezometric well.

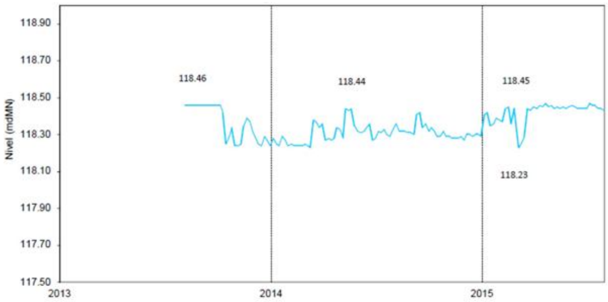

Fig. 12 − Water level variation in P_7 piezometric well.

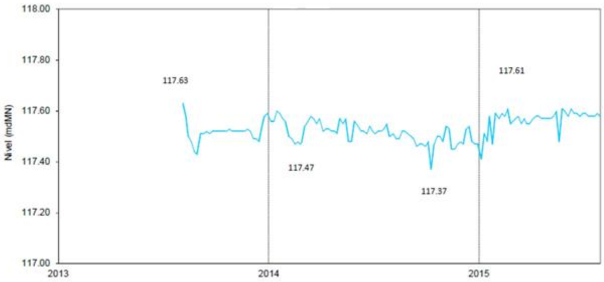

Fig. 13 − Water level variation in $P8$ piezometric well.

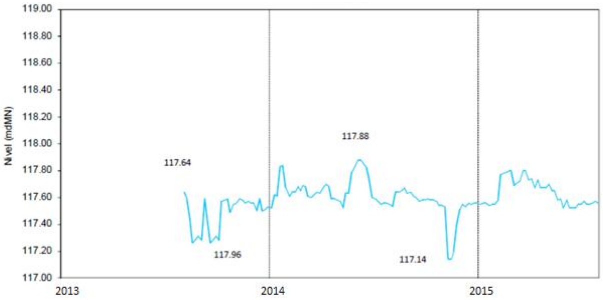

Fig. 14 − Water level variation in P_9 piezometric well.

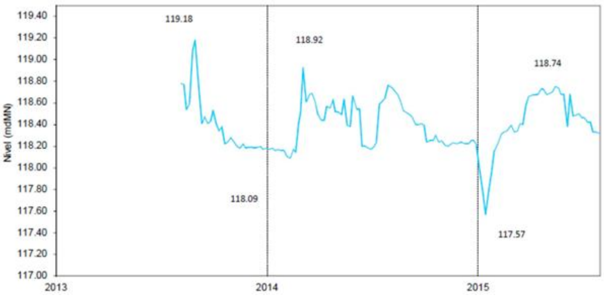

Fig. 15 – Water level variation in P_{10} piezometric well.

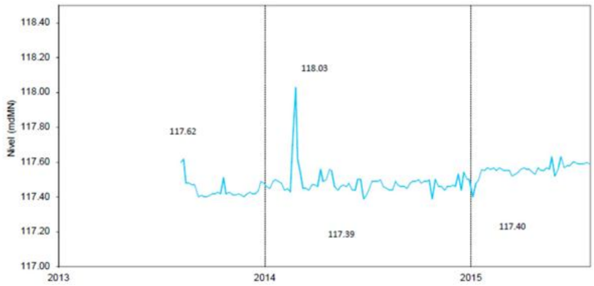

Fig. 16 – Water level variation in P_{11} piezometric well.

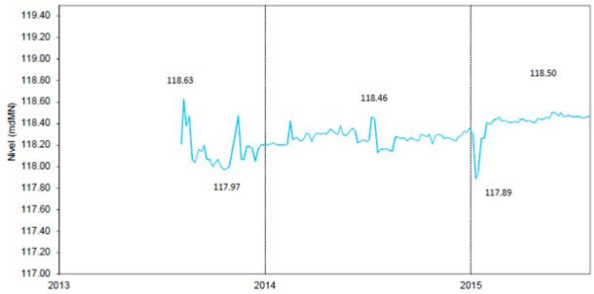

Fig. 17 – Water level variation in P_{12} piezometric well.

Graphs representing the variation of levels in the 12 piezometers at the Mileanca dam was taken from the summary report on the behavior of the Mileanca dam (NAAR-Prut-Barlad ABA, 2015).

Studying the variation of water level in the piezometric wells associated with the dam, some conclusions can be drawn:

a) correlating changes in the level of the piezometric wells must be made on each of the four measuring sections S1 (P1-P3), S2 (P4 - P6), S3 (P7 - P9) and S4 (P10 - P12);

b) in section S1, in which are disposed wells P1 - P3, it can be seen that the level variation in each of the three piezometers is not similar; so if in the P1 well the level remains constant throughout the measurement, for the other two wells P2 and P3 the level evolution does not present similarities;

c) taking into consideration that in the P1 well the readings remain constant throughout the measurement may lead to the idea that at this piezometric well there is an error on reading or even a fault;

d) in section S2, where there are disposed P4 - P6 wells there are variations in the readings during tracking but graphic variation differs for each of the three wells;

e) in section S3, wells P7 - P8 present a similar variation throughout the measurement, whereas at P9 well the variation is similar to the other two wells for the mean values, while for the minimum extreme values the variation is much higher; this can be attributed to the fact that P9 well is closer to the crest and thus to the free level of the water in the accumulation; a change in the lake water level can lead to greater variations in wells near the crest related to the ones from the downstream slope;

f) section S3 with P7 - P9 wells can be taken into consideration for a comparison between the theoretical infiltration curve and the "in situ" one because it presents a relatively similar evolution during the measurements;

g) section S4 corresponding to P10 - P12 wells shows similar variation in P11 and P12 wells (from the crest), while at P10 well, located at the downstream slope, although there are extreme variations from the other two wells, in the periods in which there are mean readings in P10, P11 and ,in P12 there are recorded higher variations;

h) it may be of interest to compare the characteristic curve for section S4 in particular for the wells P10 and P11.

5. Conclusions

The calculation of water infiltration through a dam, involves two components: the theoretical computation and the actual infiltration measured by piezometers. To calibrate the two results it is essential to achieve the readings in all piezometers of a profile (measurement section). For choosing the optimal profile, it is required to display the time variation of the piezometers level of that profile. The variation of the water level recorded in that profile should present a similar behavior in each component profile of the measuring section.

The level of the infiltration water of a homogeneous earth dam with drainage mat, resulted by piezometer readings, can vary from theoretical results. This may be influenced by a number of physical parameters related to earth homogeneity or to piezometers malfunction.

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CONSIDERENTE PRIVIND NIVELUL INFILTRAȚIILOR LA UN BARAJ DE PĂMÂNT CU SALTEA DE DRENARE

Studiu de caz barajul Mileanca

(Rezumat)

În ultimii ani, în Romania s-a manifestat un interes deosebit în dotarea barajelor cu aparatură de măsură şi control care să permită citirea parametrilor măsurați, automat. Unul din fenomenele care manifestă interes pentru a fi măsurat automat este infiltrația apei prin corpul barajelor de pământ. Se pune problema calibrării citirilor automate efectuate şi compararea acestora cu un calcul teoretic al curbei de infiltrație printr-un baraj de pământ. În prezenta lucrare, s-a încercat o astfel de comparație la un baraj de pământ dispus cu saltea drenantă.