BULETINUL INSTITUTULUI POLITEHNIC DIN IAȘI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iași
Tomul LXI (LXV), Fasc. 4, 2015
Secția
CONSTRUCȚII. ARHITECTURĂ

CONSIDERATIONS ON COMPLETION OF THE EMBANKMENT NEAR SIRET RIVER ON THE ROTUNDA–BURUIENEŞTI SECTION

BY

PETRU CERCEL[1,*], ADRIAN NICU[2], NICOLAE FLOREA[2] and CONSTANTIN NICU[3]

“Gheorghe Asachi” Technical University of Iași
[1]Faculty of Hydrotechnics, Geodesy and Environmental Engineering Iași,
[2]Faculty of Civil Engineering and Building Services,
[3]Cernaconstruct S.R.L., Iași

Received: October 22, 2015
Accepted for publication: November 10, 2015

Abstract. In recent years, due to climate change, there has been record rainfall on large areas. The rainfall led to recording historical flows on rivers in Romania. Expansion of settlements and the various uses of land have resulted in the need for technical works to protect anthropogenic activities from flooding. The dams are one of the works that can be made for flood protection. In this paper are presented theoretical and practical details on how such work is done.

Key words: embankment; flood; protection; infiltration curve.

1. Introduction

In recent years, climate change and anthropogenic developments (massive deforestation) led on the one hand to record rainfall on large areas and increasingly water drain on the slopes. This led to the recording of historical flows on the internal rivers of Romania.

---

*Corresponding author: *e-mail:* petercercel@yahoo.com

In the summer of 2010, in June, on the Siret River were recorded flows that exceeded 2,000 m^3/s, flows that led to the flooding of 306,657 km^2 (according to the official website of the Romanian Waters Administration – www.rowater.ro/EPRI%20Rapoarte/RO10_%20PFRA_Report_%2020130531. pdf. These flows have frequently overcome, according to the same site, by 2%.

At least 260 households in three communes were flooded by river Siret overflowing. Residents of villages were evacuated from Tămăşeni and Doljeşti. In Buruieneşti village, town Doljeşti 200 homes were flooded and attachments, and in Rotunda village were flooded 30 homes and annexes. In Tămăşeni commune 20 households were flooded and in Sagna commune floods entered six homes. Localities Doljeşti, Tămăşeni, Rotunda, Miron Costin, Buhonca, Sagna, Gadinti, Damuc and Huisurez remained without electricity.

After the floods has passed was the question of achieving embankment works to protect villages situated on the bank of the Siret river. This paper presents how the Siret river embankment was realized on the Rotunda-Buruieneşti section in Doljeşti village, Neamt County.

Making the embankment works involves resolving several technical problems:

a) drawing the embankment works;

b) resolving the issue of land ownership where these works will pass;

c) hydrological and hydraulic calculation on flows and levels in sections where work is to be done;

d) sizing and calculating the resistance of embankment works.

Plotting this work involves bringing together two ideas that often diverge. On the one hand it is necessary to include in the polder as many assets (buildings, property, land) which involves sudden changes in trajectory of the protection works, on the other hand it is necessary that these works have a route as rectilinear, with ample joinings of the straight sections. Solving this problem requires that the specialists who make these plots to take into account the topographical and geotechnical situation on the field, the socio-economic objectives that must be defended, but more than that it requires a good knowledge of issues and the theoretical way that such works were traced in other areas and how these works have stood the test of time.

Ownership of the land where the embankment works are to be done, is another encountered problem. In most cases, land reforms were made perpendicular to the direction of the river flow. This makes it necessary to negotiate with each owner holding narrow strips of land. It results as necessary to negotiate land acquisition with hundreds of owners.

Although, lately, Romanian law allows expropriation for public and national uses, at county or local level of these lands, most often after completion of the embankment, the task of legal expropriation problem-solving falls increasingly into the planner’s account, work which can stretch over several years.

Hydrological, hydraulic and resistance calculation. Hydrological calculation needs to be carried out by institutions/individuals with experience in processing of recorded data and constituents data interpretation of the river basin in its entirety. Hydraulic calculation will also be conducted by well-qualified staff with experience in solving these problems.

2. Theoretical Issue

2.1. Hydraulic Calculation

2.1.a Calculation of Levels

Having the flow rates with different probabilities in the section required, the calculation of the levels can be achieved using Chezy's formula:

The levels for the calculation and verification probability correspond to those calculated as natural and are calculated using Chezy's formula:

$$Q = AC\sqrt{RI};\ C = \frac{1}{n}R^{0.1666};\ R = \frac{A}{P}, \tag{1}$$

where: A is the cross-sectional area; C – Chezy's coefficient; n – roughness; R – hydraulic radius; P – wetted perimeter; I – river slope.

The embankment maximum level line in the longitudinal profile is determined from profile to profile. To this end, the embankment is divided into partial sections l_1, l_2, which in practical limit have the following elements constant:

a) the slope water surface at the maximum non-embanked level J;

b) the width of the minor riverbed plus the $B + b$ meadow;

c) area of the Ω-minor bed section;

d) Roughness ratio.

For each sector, is chosen a cross section covered by the above indicated calculation.

In the first approximation, the embanked section will connect parabolic in terms of water free surface upstream to a distance of about $l_o = 2h/J$ and downstream $l_4 = h/J$ where h is the measurement in the first, respectively in the last profile of the embanked sector and J is the calculation slope.

Level increase calculation is performed using hydraulic calculation of the gradually varied movement, going from downstream to upstream, from the point of the above indicated point. For a current sector l_2, these include:

$$\Delta z = \frac{1}{2} \cdot n_r \cdot Q^2 \cdot \left[\frac{1}{k_3^2} - \frac{1}{k_2^2}\right] \cdot l_2 \tag{2}$$

where: Δz is the difference of levels between water surface in profile 3 and one in the profile 2; n_r – minor bed roughness coefficient; k_3, k_2 – debit modules of sections consisting of profiles 3 and 2 routinely having the formula:

$$K = \frac{1}{n_r} \cdot \Omega_r \cdot a^{2/3} + \frac{1}{n_l} \cdot \Omega_l \cdot A^{2/3} \quad (3)$$

where: a is the average depth of the minor bed section plus the superimposed section and other notations are in accordance with the foregoing; Ω_r – minor bed surface corresponding to the flow calculation; Ω_l – main riverbed surface corresponding to the flow calculation.

2.1.b. Calculation of Seepage Curve Through the Designed Embankment

In common engineering practice, infiltration calculus through a homogeneous earth dam with drainage mat can be produced by using "Numerov" method described in accordance with "Infiltration calculus" - Vitalie Pietraru, Ceres Publishing House 1977.

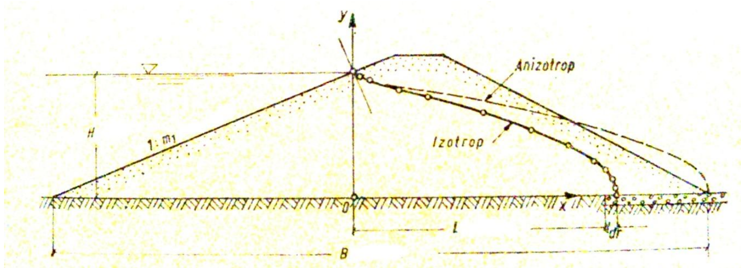

Fig. 1 – Scheme for calculating the infiltration curve by a homogeneous earth dam with drainage mat.

Free surface water infiltration can be calculated using the formula of Numerov:

$$x = \frac{H^2 - y^2}{2 \cdot \frac{q}{k}} - H \cdot F_1 + \frac{q}{k} \cdot F_2 \quad (4)$$

where:

$$\frac{q}{k} = \frac{H^2}{L + H \cdot f_1 + \sqrt{(L + H \cdot f_1)^2 + H^2 \cdot f_2}}$$

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

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

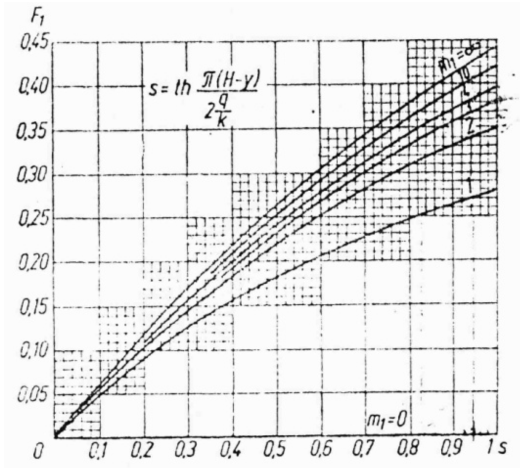

Fig. 2 – Calculation diagram of function F_1 after Numerov.

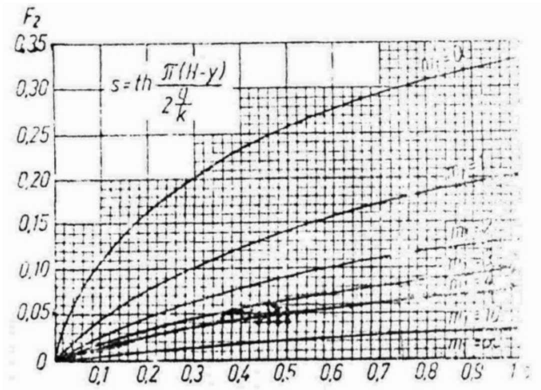

Fig. 3 – Calculation diagram of function F_2 after Numerov.

Coefficients f_1 and f_2 are related to the upstream slope and are chosen according to Table 1.

Table 1

Coefficients f_1 and f_2

m	0	1	2	2.5	3	4	5	6	8	10
f1	0	0.28	0.35	0.37	0.38	0.4	0.41	0.41	0.42	0.42
f2	0.33	0.69	0.73	0.77	0.8	0.85	0.87	0.89	0.92	0.93

2.2. The Calculation of Slope Stability of Designed Embankments

The issue of slope stability estimation is usually put in two respects:

1º In terms of slope sizing of the earthwork in the known physical-mechanics parameters of the earth (γ, Φ, C) and the main geometric characteristics imposed by functional criteria (height, depth, top width) and slopes indication are asked so that they be stable.

2º In terms of verifying already executed slopes, thereby with well defined geometry, to estimate the stability reserve.

In both cases, the sizing and the verification, the behavior of the ground work is estimated through a comparison of two safety, respectively restriction coefficients

$$Fs_{\text{effective}} < Fs_{\text{admissible}} .$$

In assessing the stability coefficient several hypotheses are considered:

a) the embankment building hypothesis;

b) operating hypothesis;

c) after passing the flood hypothesis.

It also can take into account the seismic action.

In the literature are provided the following safety factors.

Table 2

Permissible Stability Coefficients

Actions	Construction status	Work hypothesis	Slope check	*Fs* – admissible	
				No seism	With seism
Fundamental	In periods without water between dams	–	Upstream	1.30	1.30
			Downstream		
Accidents	Operating during floods	The enclosure is filled to maximum level	Downstream	1.50	1.20
	Sudden drain	From the maximum level	Upstream	1.20	No check

2.2.1. Description of the Galena Program

By using it is easy to calculate the slope stability at different times of lake operation.

The data required to start the program are those related to geometric features of the slopes, geotechnical properties of the earth (specific weight, cohesion, angle of internal friction), piezometric level in the body of the dam and the water in the lake, any charges appearing in the dam and the seismic power that can act on it.

The program is built for stability calculation purposes using one of three methods of calculation: Bishop, Sarma or Spencer Wright.

3. Application of Theoretical Matter for "Embankment Works of Siret River on the Rotunda – Buruieneşti Section"

3.1. Levels Calculation

To perform hydraulic calculations were selected 12 cross sections of the riverbed and floodplain of the river Siret, in the Rotunda – Buruienesti area. Among these sections were considered 5 sections that are hydraulically optimal.

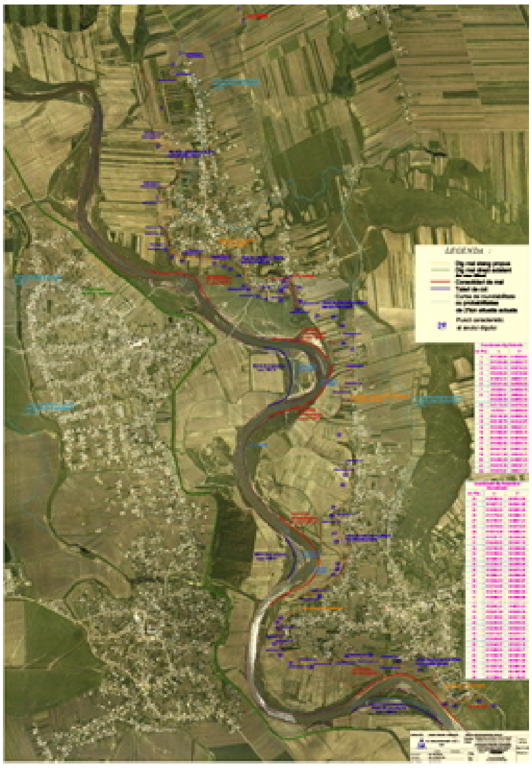

Fig. 4 –The embankment works.

In these sections, the calculation was done by spreadsheet, considering roughness n = 0.04. For example, the calculation is presented for Section 3.

With the resulted levels, it started to calculate the seepage curve and slope stability. Respecting the infiltration curve algorithm resulted the curve profile.

Table 3

Hydraulic Calculation of the Levels in Profile 3

Level	Characteristic level	Wet area	Wet perimeter	*R*	*n*	*c*	*i*	*Q* mc/s	*Vm* m/s
190.46	Current crest of Tămăşeni embankment	–	–	–	–	–	–	–	–
190.06	Designed crest of Buruienești embankment	2,062.75	411.78	5.01	0.04	32.70	0.0005	3,375.92	1.64
189.87	Level corresponding to 0.1% flow	1,962.002	410.71	4.78	0.04	32.44	0.0005	3,111.00	1.59
189.35	Level corresponding to 1% flow	1,758.4	409.47	4.29	0.046	27.72	0.0004	2,019.85	1.15

3.2. The Calculation of Slope Stability

Analyzing the geotechnical study conducted for this paper revealed the following conclusions:

1º On the route of the designed defense embankment, the intercepted stratification has the character of fluvial deposits consisting of fine coarse rocks or gravel sands commencing on average from 3.10 to 3.20 m deep and are followed up to 6 m deep. These deposits are covered by less consolidated complex of sandy dust - fine silty sands.

2º Allowable pressure in the dam foundation, P_{adm} = 175,…,200 kPa.

3º Geotechnical characteristics of soils are presented in the Table 4.

4º In the pits, the lithological column studied indicated a stratification of sandy dust - clay powder in plastic consistent state.

5º Hydrogeological, the permeability of the layers is as follows: permeable rocks (silty formations - sand, fine sand) where k = 4.10 - 10-7 cm/s and very permeable rocks (sand, gravel - sandy gravels) where k > 10 to 1 cm/s.

Table 4

Geotechnical Characteristics of the Soil in the Designed Embankments

Earth type	Φ, [º]	C, [daN/cm^2]	γ, [t/m^3]
Sandy dust	20	0.06	1.45,…,1.5
Clay powder	18	0.10	1.48,…,1.55

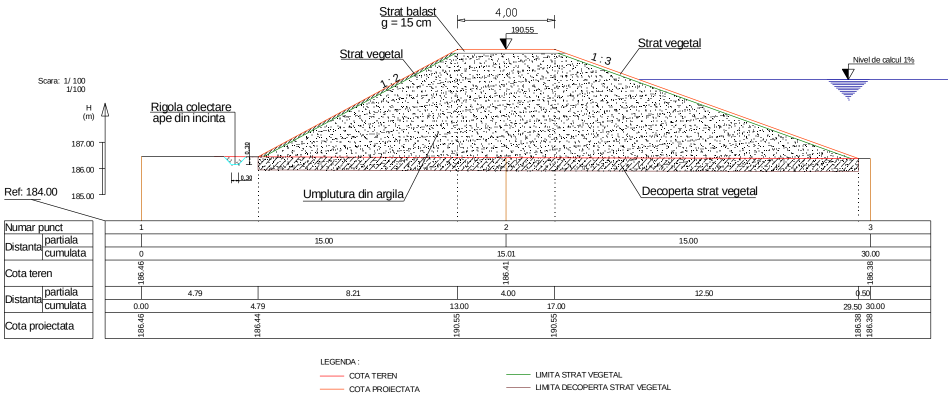

Fig. 5 – Cross section through the proposed embankment.

Geotechnical and geometric data of the embankment were introduced in the "Galena" program. Three scenarios were run: enclosure full (during the flood), drained enclosure (after the flood) and normal operation (without water between embankments).

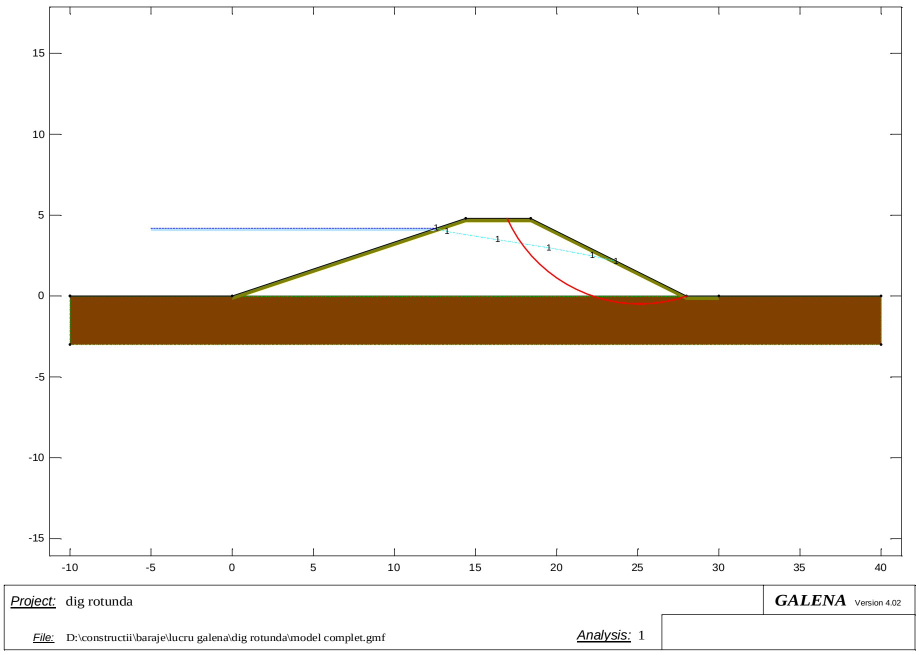

Fig. 6 – Calculation scheme for slope stability.

After running the program, the following results yielded:

Table 5

Hypothesis	Slope towards Siret	Slope towards locality
The enclosure filled with water up to the maximum	6.3	1.64
Immediately after emptying the enclosure between embankments (infiltration curve remaining above)	1.93	1.64
Normal operation (no water inside the enclosure)	2.16	1.77

4. Conclusions

The calculated coefficients confirm that slopes are chosen properly but slope from the village needs attention, because the stability coefficient is at the allowable limit.

Filler from the embankment has a low cohesion; this is reflected in a low stability to a cohesive material. Consequently, this leads to limitations on the embankment slopes choice.

The slope of the embankment towards the Siret river was chosen 1:3 with reasons to avoid erosion during floods (water speed at the embankment's base, during the flood, may reach 1.1 m/s) and a lower slope may lead to material transportation from the embankment.

Geometry of the embankments is:

a) M1 – the slope towards the river 1: 3;

b) M2 – the slope toward the protected area 1: 2;

c) L = 4 m (width of the embankment’s top).

REFERENCES

Giurma I., Crăciun I., *Hydrology* (in romanian). Politehnium Publ. House, Iaşi, 2008.

Pietraru V., *Seepage Calculation* (in romanian). Ceres Publishing House, 1977.

Popovici N., *Embankments, Water Management and Regularisations* (in romanian). Design guideline, Politechnical Institute Iaşi, 1986.

* * * CERNACONSTRUCT Iaşi (chief project engineer. Nicu Adrian), *Embankment works on Siret River in the Rotunda - Buruieneşti section, Doljeşti village, Neamt County* (technical design specifications and details), Iaşi, 2010-2011 (in romanian).

CONSIDERENTE PRIVIND REALIZAREA LUCRĂRILOR DE ÎNDIGUIRE A RÂULUI SIRET PE TRONSONUL ROTUNDA–BURUIENEȘTI

(Rezumat)

În ultimii ani, datorită schimbărilor climatice, s-au înregistrat precipitații record pe suprafețe extinse. Aceste precipitații au dus la înregistrarea de debite istorice pe râurile din Romania. Extinderea localităților şi a diverselor folosințe ale terenului, au dus la necesitatea realizării de lucrări hidrotehnice, care să protejeze activitățile antropice de inundații. Digurile constituie una din lucrările posibil a fi realizate pentru protecția împotriva inundațiilor. În această lucrare, sunt tratate teoretic şi prezentate practic, cum se realizează o astfel de lucrare.