CONTROLLED DRAINAGE AND SUBIRRIGATION - THE REVERSIBLE FACILITIES -

REVERSIBILITATEA DRENAJULUI ÎN SUBIRIGAȚIE

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Abstract: *The purpose of this publication is to provide the reader with a general understanding of how agricultural drainage waters can be managed to help balance production and environmental goal. This publication was designed to help persons who have a good understanding of agricultural drainage extend beyond their current knowledge of drainage water management.*

Rezumat: *Scopul acestei lucrări este de a înțelege cum apa rezultată din drenaj poate fi folosită în alte scopuri şi cum putem asigura o balanță între o recoltă bună şi mediul înconjurător fără a-l polua. Modul în care distribuim apa din drenaj poate avea importante consecințe asupra recoltei, profitului şi mediului de aceea trebuie să folosim o strategie eficientă: reversibilitatea ei în subirigație.*

Key words: *drainage, control, subirrigation, strategy, reversible*
Cuvinte cheie: *drenaj, control, subirigație, strategie, reversibilitate*

INTRODUCTION

Subsurface drainage structures may be employed also in the case of sub-irrigations. The double use reduces the costs of these structures. For this purpose the underground drainage structure must be first designed and then verified as a sub-irrigation system.

MATERIAL AND METHODS

Two layered soil subsurface drainage structure is designed using ERNST relationship completed by DAVID for a real drain with filter [1].

The basic scheme of this structure is depicted in figure 1 where: z - is the drainage norm, h - is the hydraulic head, K_1, K_2 - are the hydraulic conductivities of the two soil layers, D_0 - is the distance between the drain separation layer (the distance corresponds to the radial flow), $D_1 = D_0 + 0{,}5 \cdot h$ - is the water level above the drain (the distance corresponds to the horizontal flow in K_1 layer), D_2 - is the thickness of the layer below the drain, characterized by the hydraulic conductivity K_2, $D_v = h$ - the vertical distance of the vertical flow, d_0 - is the diameter of the drain tube, L - is the drains distance.

Ernst relationship for the calculation of the distance between ideal drains is:

$$h = h_v + h_o + h_r \qquad (1)$$
$$= \frac{q \cdot L}{K} \cdot \left(\zeta_o + \zeta_v + \zeta_r\right) = \frac{q \cdot L}{K} \cdot \zeta_0$$

where h_o, h_v, h_r are the hydraulic heads losses due to the horizontal, vertical and radial flow, respectively, and ζ_0 the total loss coefficient with an ideal drain. The resistance coefficients,

ζ_o, ζ_v, ζ_r, corresponding to three flow types are calculated according to the relationships below:

$$\zeta_o = \frac{L}{8\cdot(D_0 + 0{,}5\cdot h)};\ \zeta_v = \frac{d_0 + h}{L};\ \zeta_r = \frac{1}{\pi}\cdot\ln\frac{2}{\pi}\cdot\frac{D_0}{d_0} \qquad (2)$$

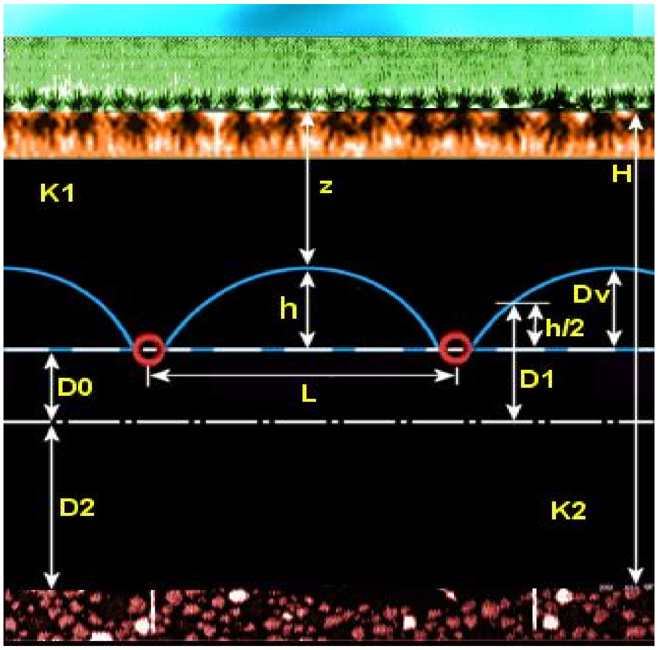

Figure 1. Design of the subsurface drainage structure (scheme)

If the drain are real - with discontinuous slits - and overcastted with a filter, then DAVID [2] proposes the addition to the ERNST relationship with a term for the load loss at the filter drain entrance, δh_{if},

$$h = h_0 + \delta h_{if} = \frac{q\cdot L}{K}\cdot(\zeta_0 + \zeta_{if}) \qquad (3)$$

The resistance coefficient at the filter drain entrance is given by the relationship

$$\zeta_{if} = \alpha\cdot\left[\ln\left(\frac{1}{\sin\left(\frac{nb}{2d_0}\right)}\right) + \frac{1-\chi}{2\chi}\cdot\ln\left[\left(A_1+\sqrt{A_1^2+1}\right)\cdot\left(A_2+\sqrt{A_2^2+1}\right)\right]\right] + \beta\cdot\left[\ln\left(\frac{1}{\sin\left(\frac{\pi\cdot l}{2B}\right)}\right) + \frac{1-\chi}{2\chi}\cdot\ln\left[\left(B_1+\sqrt{B_1^2+1}\right)\cdot\left(B_2+\sqrt{B_2^2+1}\right)\right]\right] \qquad (4)$$

with

$$A_1 = \frac{d_0}{nb} \cdot \frac{\left(\frac{d_f}{d_0}\right)^n - 1}{\left(\frac{d_f}{d_0}\right)^{n/2}}; \quad A_2 = \frac{d_0}{nb} \cdot \frac{\sqrt{\left(\frac{d_f}{d_0}\right)^{2n} - 1}}{\left(\frac{d_f}{d_0}\right)^{n/2}} \tag{5}$$

$$B_1 = \frac{\sinh \frac{\pi (d_f - d_0)}{2B}}{\sin \frac{\pi \cdot l}{2B}}; \tag{6}$$

$$B_2 = \frac{1}{\sqrt{2}} \cdot \sqrt{\frac{\sqrt{\sin^4 \frac{\pi \cdot l}{2B} + \sinh^2 \frac{\pi \cdot (d_f - d_0)}{B}}}{\sin^2 \frac{\pi \cdot l}{2B}} - 1}$$

where:

n- is the number of slits situated on the circumference of the drain, b - is the width of the slit, l - is the length of the slit, B - is the distance between slit, d_f - is the filter diameter.

The coefficients α and β are calculated according to the relationship below:

- In the case of the longitudinal slit (for $l > b$) it takes the form:

$$\alpha = \frac{2 \cdot \mathrm{B}}{\mathrm{n} \cdot \pi \cdot \ell}; \quad \beta = \frac{2 \cdot \mathrm{B}}{\pi^2 \cdot \mathrm{d}_0}, \tag{7}$$

- In the case of the transversal slit (for $l < b$) it takes the form:

$$\alpha = \frac{2}{\mathrm{n} \cdot \pi}; \quad \beta = \frac{2 \cdot \mathrm{B}}{\pi \cdot \mathrm{n} \cdot \mathrm{b}}. \tag{8}$$

The coefficient $\chi = K_f / K_0$ represents the proportion between the hydraulic conductivity coefficient of the filter, K_f, and of the soil around the drain, K_0 respectively.

The distance between the drains, L, results from the second order equation in L, which is given by the relationship (3) (only the positive term is retained). After the calculation of this distance, practically the design of the drainage structure is finished. Next step consists in the verification of the structure's fit as a sub-irrigation system (figure 2) meaning that it may be used reversibly.

The goal of the sub-irrigation verification is to determine the level difference $h_{sub} = H_0 - H_m$. The difference represents the total load loss which secures the water reserve at the root level. The basic scheme of this structure is depicted in figure 2. The significance of the notations is as follows: ε - water flow lost by evapotranspiration, p - width of phreatic water, H_0 - width of the saturated soil zone at the drain, H_m - width of the saturated soil zone midway between the drains, D_0 - the distance between drains and the impermeable layer, $L_{dr} = L$ - the drains distance, H - the height of the impermeable layer, K - hydraulic conductivity of the soil.

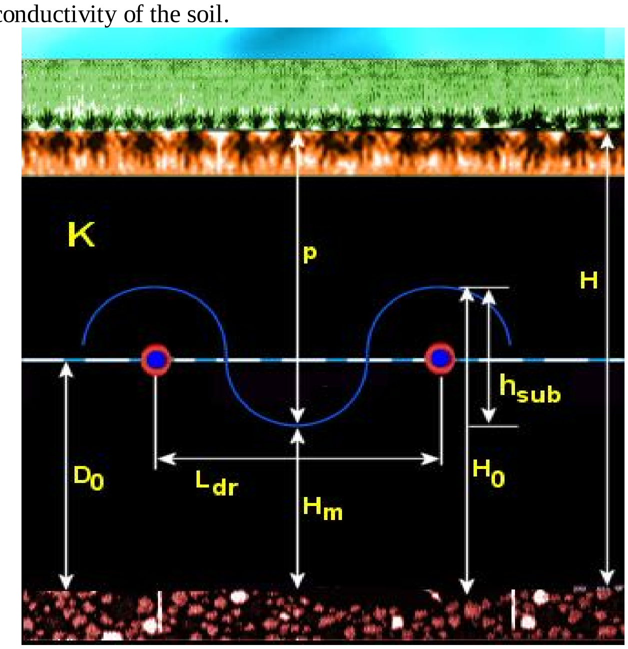

Figure 2. Design of the subirrigation structure (scheme).

The total hydraulic head loss is composed of two components

$$h_{sub} = h_o + h_r \tag{9}$$

where: h_o - is the hydraulic head loss due to the horizontal movement, h_r - is hydraulic head loss due to radial movement around the drain. These losses are defined by the relationships below

$$h_o = \frac{\varepsilon L}{8KT_e} \quad \text{with} \quad T_e = \frac{H_0 + H_m}{2}, \tag{10}$$

$$H_0 = H - z - h_{if} - h_{ld}, \qquad H_m = H - p;$$

$$h_{if} = \frac{\varepsilon L_{dr}}{2K} \cdot \zeta_{if}, \tag{11}$$

$$h_{ld} = \frac{8(\varepsilon L_{dr})^2}{\pi^2 g d_0^4} \cdot \left[\left(\frac{\lambda}{3} \cdot \frac{X_{dr}}{d_0} \right) - 1 \right], \tag{12}$$

From these relationships h_{if} is the hydraulic head at real drain with filter entrance, h_{ld} is the hydraulic head loss along the drain of $X_{dr} = H/i$ long and i slope, $g = 9.81\left(m/s^2\right)$, $\lambda = 0.04$ is roughness coefficient.

$$h_r = \frac{\varepsilon L^2}{4KH_m}\left[\frac{\alpha-1}{\alpha+1} - \frac{2H_m}{\pi L_0}\cdot \ln\left[\begin{array}{l} 2^{\alpha}\cdot\left[\left(1+\cos\left(\frac{\pi D_0}{H_0}\right)\right)+\frac{\pi r_0}{H_0}\cdot\sin\left(\frac{\pi D_0}{H_0}\right)\right]^{\alpha} + \\ +\left(1+\cos\left(\frac{\pi D_0}{H_0}\right)\right)^{\alpha} \end{array}\right]\right] \tag{13}$$

with

$$\alpha = \frac{H_0}{H_m}. \tag{14}$$

The validation criterion of the resistance of the drainage structure and of the reversible use (meaning, sub-irrigation) is described by the following relationship

$$(H_c + z) < H \tag{15}$$

where

$$H_c = H_m + h_{sub} + h_{if} + h_{ld} \tag{16}$$

and represents the water height in the collecting channel.

RESULTS AND DISCUSSIONS

Computer simulations were done involving the equation (1-8) for subsurface drainage, and (9-16) for sub-irrigation validation. Two examples were taken in account, first with hydraulic head *h = 1.1 mm/day* and second with *h = 0.6 mm/day*. Results from the first example with two values for *H = 3.00 m* and *H = 4.75 m* are presented in table 1. Results from the second example with two values for *H = 3.00 m* and *H = 4.75 m* are presented in table 2.

Both examples consider two situations concerning the drains. First situation considers an ideal drain that means no ζ_{if} coefficient involved. The second situation considers the real drain with filter that means real valued of ζ_{if} coefficient.

Table 1

Initial parameters

q = 0.01 mm/day z = 0.6 m h = 1.1 mm/day	D_0 = 0.5 m D_1 = 0.8 m D_2 = 2.0 m	d_0 = 0.065 m d_f = 0.073 m	l = 0.001 m b = 0.005 m B = 0.012 m		p = 1.6 i = 0.02 λ = 0.04		
K_1 (m/day)	K_2 (m/day)	K_{fc} (m/day)	ζ_{if}	L (m)	h_{sub} (m)	(H_c+z) (m)	H (m)
0.6	2.2	1.32	-	41.32	2.85	4.95	3.00
0.6	2.2	1.32	0.2533	36.90	2.24	4.33	3.00
0.6	2.2	1.32	-	41.32	1.00	4.87	4.75
0.6	2.2	1.32	0.2533	36.90	0.77	*4.63*	*4.75*

Table 2

Initial parameters

q = 0.01 mm/day z = 0.6 m h = 0.6 mm/day	D_0 = 0.5 m D_1 = 0.8 m D_2 = 2.0 m	d_0 = 0.065 m d_f = 0.073 m	l = 0.001 m b = 0.005 m B = 0.012 m		p = 1.6 i = 0.02 λ = 0.04		
K_1 (m/day)	K_2 (m/day)	K_{fc} (m/day)	ζ_{if}	L (m)	h_{sub} (m)	(H_c+z) (m)	H (m)
0.6	1.0	1.1	-	22.26	0.75	*2.83*	*3.00*
0.6	1.0	1.1	0.3435	19.20	0.54	*2.60*	*3.00*
0.6	1.0	1.1	-	22.26	0.22	*4.05*	*4.75*
0.6	1.0	1.1	0.3435	19.20	0.15	*3.97*	*4.75*

Drains distance L, decreases with 4.16 % (table 1) in first example, from the ideal drain situation to real drain with filter situation. In second example the drains distance L, decreases with 13.74 % (table 2) in first example, from the ideal drain situation to real drain with filter situation. These means that the real drain with filter needs a smaller drains distance.

Sub-irrigation validation fails in the first three cases of the first example because the $(H_c + z)$ values are greater than H values. The forth case generates subsurface drainage structure that can be used in sub-irrigation, as the validation criterion $(H_c + z) < H$ is satisfied (table 1).

In the second example all the four cases generates subsurface drainage structures that can be used in sub-irrigation, as the validation criteria $(H_c + z) < H$ are satisfied (table 2). Regardless of H values, the $(H_c + z)$ values are smaller in the situation of real drain with filter than ideal drain. These results mean that those subsurface drainage structures are more stable to sub-irrigation uses.

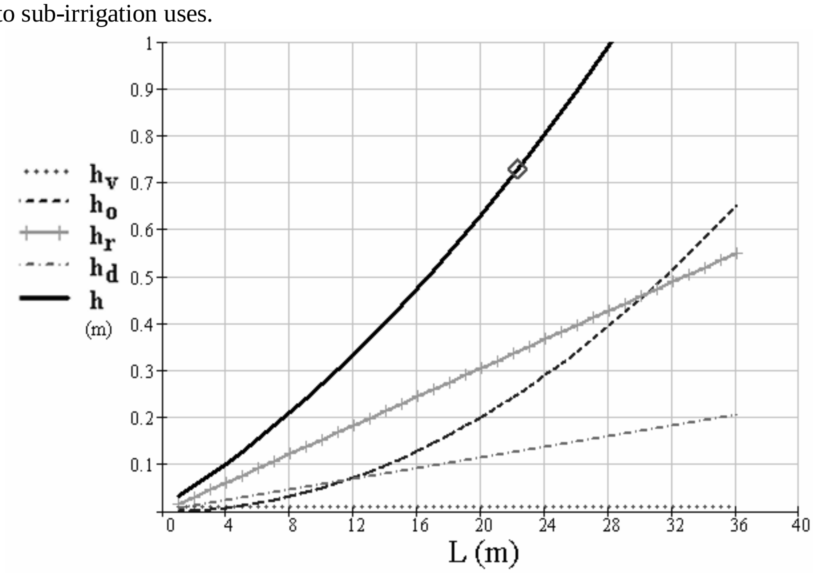

Figure 3. Hydraulic heads: h_o - for horizontal flow, h_v - for vertical flow, h_r - for radial flow and h_d - for drain entrance flow

Considering the real drains with filter (i.e. the DAVID term), one can classifies the hydraulic heads losses. Figure 3 consists in such a classification of all five hydraulic heads with respect of a certain drain distance, L domain. The point (*h = 0.6 m*, *L = 22.26 m*), from the second example – ideal drain situation, is marked with a diamond symbol.

CONCLUSIONS

This paper studies the effect of using a real drain with filter in subsurface drainage design and the opportunity of its sub-irrigation validation. Computer simulation results points out that real drain with filter subsurface drainage systems are more robust to sub-irrigation use.

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