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THE SEEPAGE THROUGHTHE EARTH DAMS WITH A VERTICAL DRAIN : AN EXPERIMENTAL STUDY

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ABSTRACT

The flow of water through dams and their foundations and the accompanying pressures and gradients that exist, have long been recognized by engineers as important factors in dam design. And one of the major problems encountered when designing Earth dams is the choice and design of systems of drainage that are able to protect the dams from undesirable effects. Although the existence of a number of satisfactory drainage systems allowed the construction of many projects, the lack of control of seepage flow and the position of saturation curve in the drain may threaten the security of these constructions and render them uneconomical. The paper presented herein reports that the results obtained from the experimental study of a homogeneous embankment on pervious foundation. Relations have been obtained which can be help in the control of the quantity of discharge in the vertical drain, which permit a better management of earth dams.

Key Words : Seepage, Earth dams, Chimney drain, Position of drains, Flow rate

INTRODUCTION

The earth dams and rock-fill dams are generally built of locally available materials in their natural state with a minimum of processing and they are subject to seepage through the embankment, foundation and abutments, therefore we devoted this study to the search of solutions of problems encountered in the earth dams after their construction. The principal difficulties for the earth dams are the infiltration of water through it which leads to the piping phenomenon and the migration of fine particles outside the earth dam, what causes the slip of the slope downstream of the earth dam and compromises the stability of the structure. Therefore, it is necessary to develop special processes such as the drains and the filters and to choose the type of the most effective drain to limit the progression of the piping phenomenon. We performed a study on a reduced model, of a homogeneous earth dam with chimney drain the first on an impervious foundation and the second on a pervious foundation and we proposed a correlation to determine the best position of the drain in the homogeneous earth dams for the first[1] and the flow rate can be directly determined for a given head of water and slope of the upstream for the second. Finally a comparative study of the experimental data with results obtained by numerical simulation performed with commercial software [SEEP] was carried out.

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MATERIAL AND METHODS

Experimental model

A small-scale model was built which is geometrically similar to the real system. This model represents a homogeneous earth dam with a vertical drain on a pervious foundation.Sand has been used as a permeable medium for the body of the earth dam and of gravel for the drain. The piezometricprickings laid out on the two zones with dimensions of the tank make it possible to know the actual values of the head of water along the trajectory of flow and highlight the burden-sharing of water in the seepages.

Model of earth dam on pervious foundation

The model is built in a glazed tank which length is 145cm, width 17.8cm and height 60 cm. There are 14 piezometers located along the tank. Moreover, one established in the other side 4 piezometers for following the flow well.

When steady-state flow is reached, the flow can be traced by dye injection at various points along the upstream boundary close to the transparent wall to form the traces of streamlines, and heads determined by small piezometers.[2] Upstream and downstream from the dam of the devices are designed to maintain at the ends of the tank the desired load **(Fig. 1 to Fig. 2).**

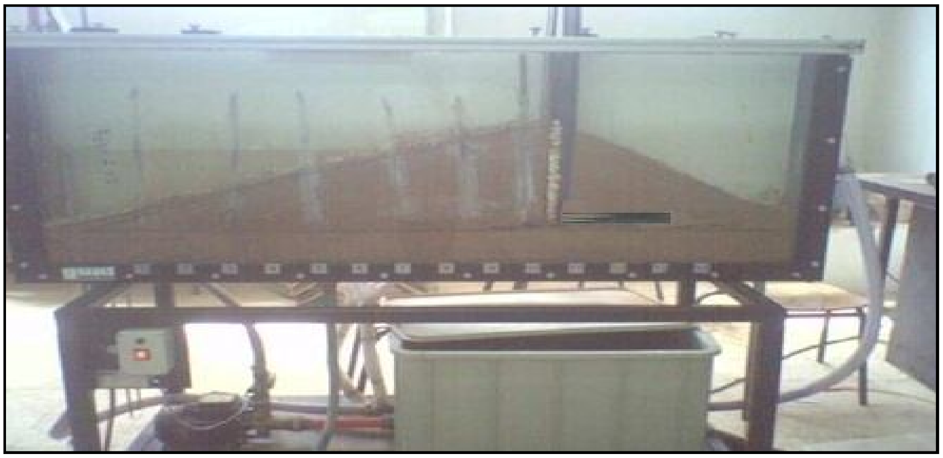


Fig.1 (a) : General view of earth dam on an pervious foundation

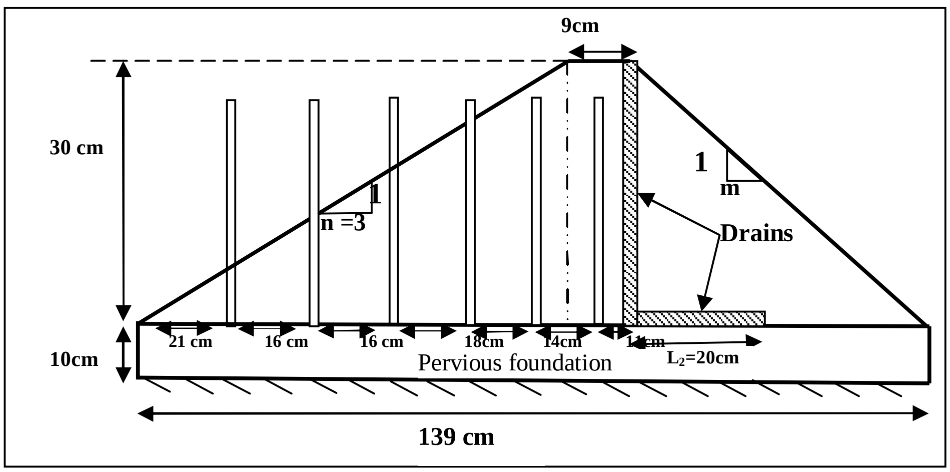


Fig. 1(b) : Detailed view of earth dam on an pervious foundation

Fig. 2(a) : General view of sand box

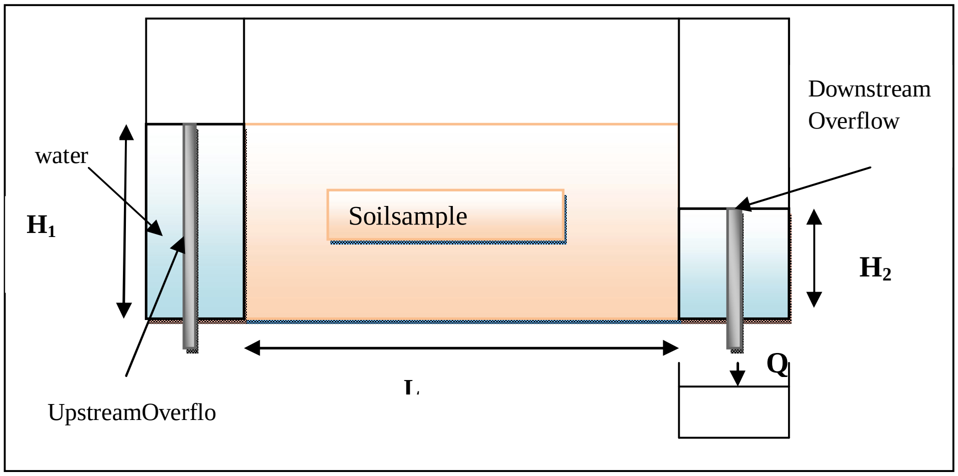


Fig. 2(b) : Detailed view sand box

For each test one imposed the head of water upstream (H) and noted quantity of discharge (Q). That was carried out by maintaining the slope of the river (1/n) constant. All the data are presente in **Fig. 3**. We changed the slope of the upstream by keeping the same average

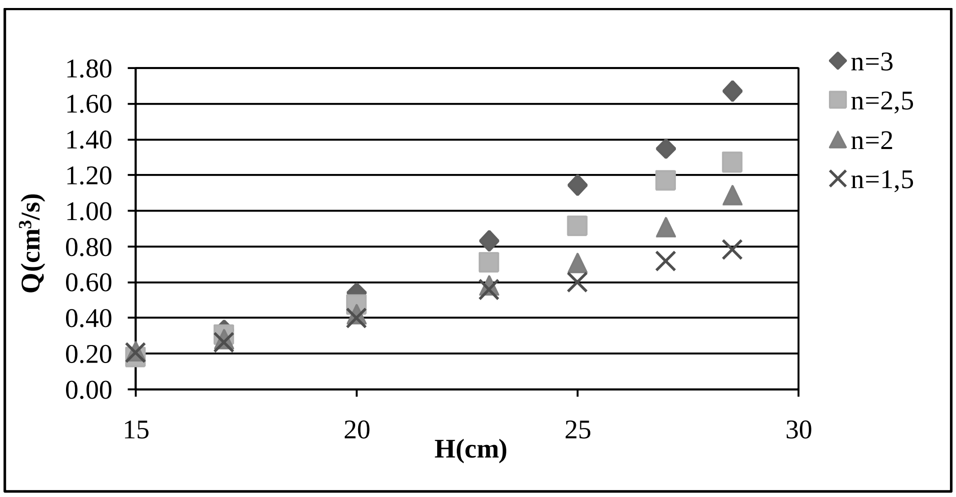


Fig. 3 : Measurements of the flow rate in drain versus the head of water upstream

hydraulic gradient, One notes that the quantity of discharge (Q) increases with the increase in the slope by what we have an increase in the cross-section of water stream discharge.

RESULTS AND DISCUSSION

Determination the position of the drains

One can determine the best position of a vertical drain in a homogeneous earth dam according to the maximum head of water, the slope of the upstream and the critical hydraulic gradient of the material to be used in the earth dam[3,4] for our case one has for sand fine I_{cr}=0,38. Assuming that the curve of saturation (phreatic line) has a linear shape **Fig. 4**, we proposed the following relationship.

$$L_d = nH_m + \frac{H_m - h_d}{I_{cr}} \qquad (1)$$

whereH_m = maximum head of water, h_d = height of the drain, I_{cr} = critical gradient of material used, n = slope of the upstream, L_d= position of the drain.

The flow rate in the chimney drain of the earth dam on pervious foundation

We can determine the quantity of discharge for a given head of water and the slope of the upstream by using the following empirical relationship, under the following condition :

$$\frac{k_{1h}}{k_{2h}} = 8.8 \text{ and } \frac{k_{1v}}{k_{2v}} = 1.43$$

$k_{h1,2}$ = coefficient of horizontal permeability(of the dam and the foundation respectively) ; $k_{v1,2}$ = coefficient of vertical permeability (of the dam and the foundation respectively).

$$Q = (0.1\sqrt{\frac{k_1}{k_2}})^{0.001} . e^{\left[0,0775 . n^{0,125} . H + \frac{0,1087}{n}\right]} \quad (2)$$

Q = the flow rate[cm^3/s.ml]; H= the head of water upstream [cm]; $k_{1,2}$ = coefficient of horizontal permeability(of the dam and the foundation respectively) n = slope of the upstream. The comparisons of results of this relationship (2) with the results of the experimental data is represented in the following **Fig. 5**.

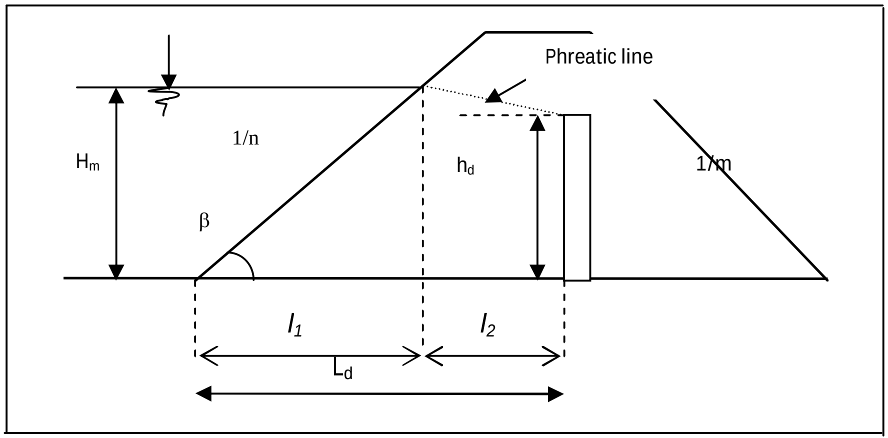
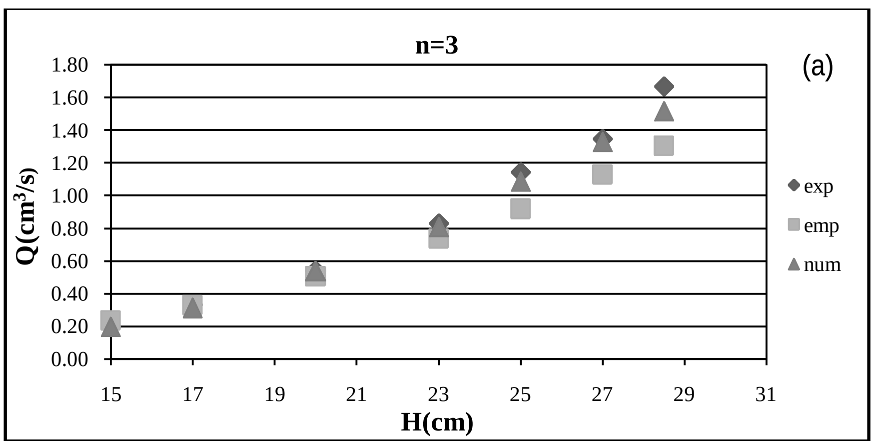
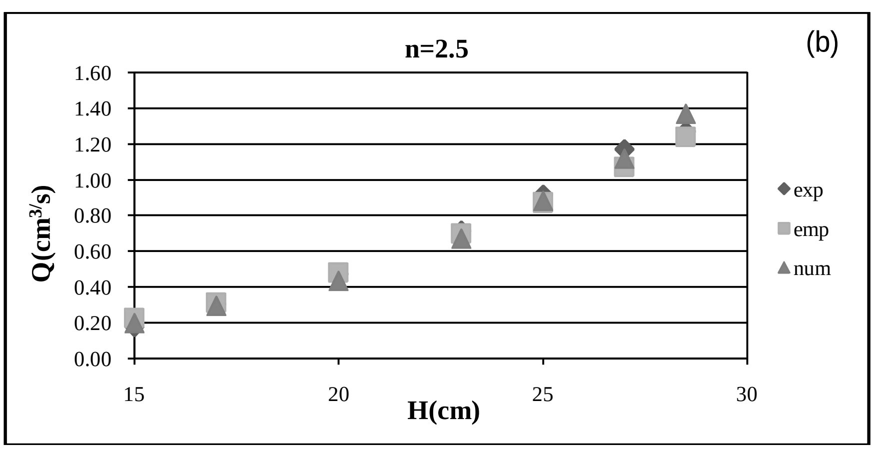
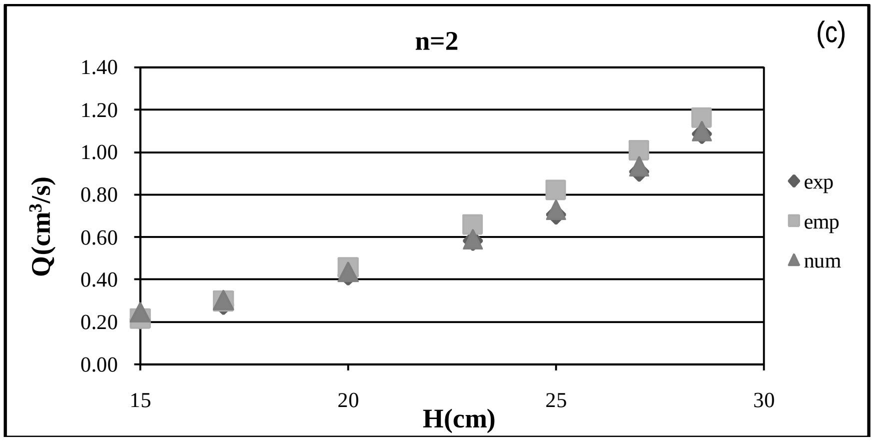


Fig. 4 : Homogeneous embankment on impervious foundation







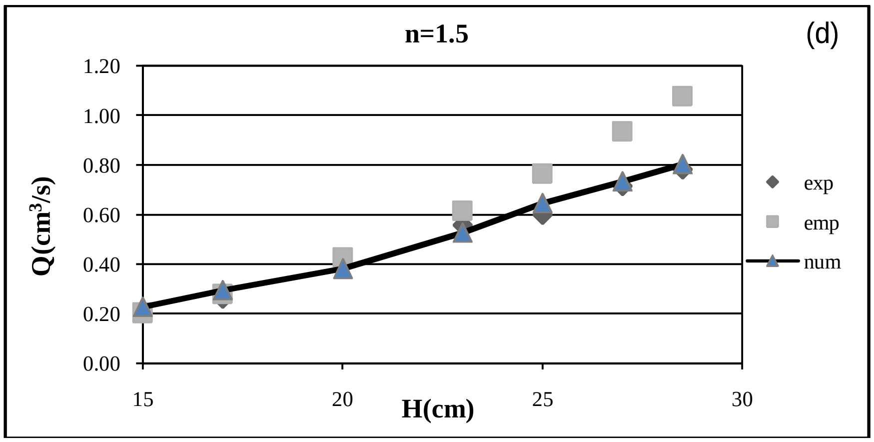


Fig. 5 : The diamond represents the experimental results of the tests the square represents the results obtained with equation (2) and the triangle represents the numerical results

We observe a good agreement between the curves obtained by the empirical formula and the experimental data and the numerical results obtained with "SEEP". The variation of the flow rate in the drain (Q) according to the head of water (H) given by the three procedures of calculation are well adjusted except for the case n=1.5 where there is a small shift between the curves.

CONCLUSION

The models developed in this study make it possible to design the most effective position of the drains in the earth dams in impervious foundation, assuming that the phreatic line has a linear shape and one can determine the quantity of discharge for a given head of water for the earth dams in pervious foundation in steady seepage. Moreover, these equations are simple to apply and can be used to design and analyze any homogeneous dam with a chimney drain, when the most of the ordinary seepage analysis can be carried out by general commercial software. These very encouraging results enable us to consider the prediction of the infiltrations through the earth dams as well as the piping phenomena which are often at the origin of many dramatic accidents.

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