AN EXPERIMENTAL STUDY FOR SEEPAGE THROUGH AN EARTH DAM WITH A PIPE DRAIN

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ABSTRACT

The problem studied in the present paper is seepage through an earth dam, based on a horizontal impervious base, with a pipe drain. Experiments are carried out using a Hele-Shaw model to measure both drain discharge (q_d) and escaped discharge (q_s) corresponding to different values of the upstream retained head (H) for a constant value of the spacing (L), drain diameter (d) and drain depth (D) measured vertically from the impervious base. Effects of spacing, drain diameter and drain depth on discharges (q_d and q_s) are also studied. Free water surface is recorded experimentally. The measured drain discharge and the recorded free water surface are compared with theoretical results given by applying El-Ganainy equations [2].

NOTATION

- a — half distance between the two prespex plates of the experimental model,
- d — drain diameter = 2r (=2cm in all experiments),
- D — drain depth measured vertically from the impervious base,
- g — acceleration due to gravity,
- H — the retained head upstream the dam,
- K — hydraulic conductivity of the soil = $a^2 g/3\upsilon$,
- q_d — drain discharge,
- q_s — escaped discharge to the toe of the dam,
- α — angle of inclination of the upstream face of the dam, (=45°),
- θ — angle of intersection of the free water surface with drain as shown in Figure (7)
- υ — Kinematic viscosity of the oil at the experimental temperature, cm^2/sec.

INTRODUCTION

Seepage through an earth dam was studied for different shapes of filter. Kozeny [6] used a horizontal toe drain located at the downstream portion of the dam. Casagrande [1] extended Kozeny's solution to include dams with trapezoidal toe drain and slope drains. Numerov [7] solved the problem for trapezoidal toe filter. Hathoot [4] and [5] also solved the same problem using horizontal and trapezoidal toe filters. Rezk [8] gave a solution using an "L" shaped filter. For the same problem studied experimentally in this paper, El-Ganainy [2] established the complex potential, the equipotential and stream functions. He derived the discharge equation in the following from:

$$q_d = m \tan^{-1} \frac{2H(H\cot\alpha - L)}{(H\cot\alpha - L)^2 - H^2 + D^2} - 2UH\sin\alpha \quad (1)$$

where: m = the strength which is denoted by the following equation:

$$m = -2KH\left[1 - \frac{D}{rH}(L - H\cot\alpha)\right] / \left\{\ln[(H\cot\alpha - L)^2 + (H-D)^2][H\cot\alpha - L)^2 + (H+D)^2] - \frac{(L - H\cot\alpha)}{r}\ln(r^4 + 4D^2r^2)\right\} \quad (2)$$

U = the steady stream which is given as follow:

$$U = \frac{-KD - \frac{m}{2}\ln(r^4 + 4D^2r^2)}{2r\sin\alpha} \quad (3)$$

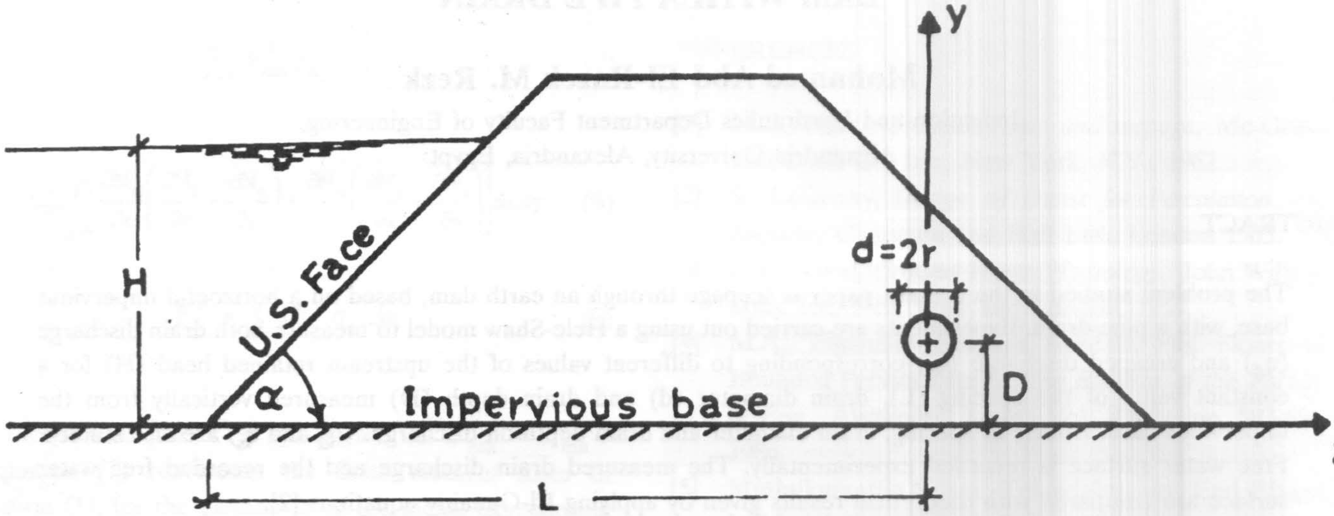

Figure 1. Geological section of earth dam with pipe drain and coordinates taken by El-Ganainy [2].

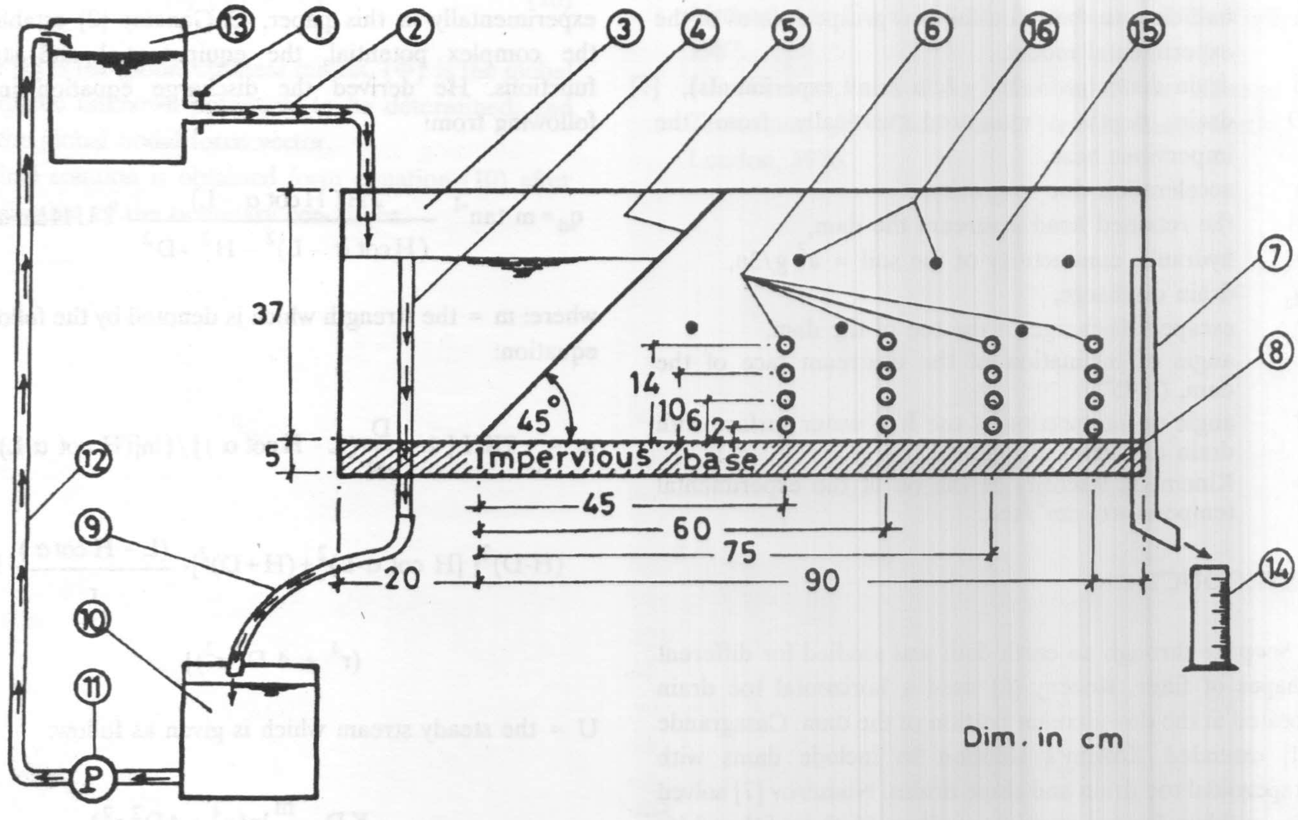

Figure 2. An experimental model.

The free water surface also was drawn by El-ganainy [2] according to the following equation:

$$Ky = 2 U x \sin \alpha - \frac{m}{2} \ln [x^2+(y-D)^2] [x^2+ (y+D)^2] \quad (4)$$

In the present study, using Hele-Shaw model, effect of spacing (L), drain depth (D), and drain diameter (d) on both discharge and shape of the free water surface is studied experimentally. Quantity of seepage entering the drain and that escaped to the toe of the dam are measured.

Comparison is made between experimental results and those given by applying El-Ganainy equations [2].

EXPERIMENTAL MODEL

Seepage through an earth dam with a pipe drain is investigated experimentally using Hele-Shaw model. The model, which is shown in Figure (2), Consists of two vertical prespex plates (15) 1100x420x10 mm. A constant spacing between the two plates is kept by using klingarite washers (16) 1.5 mm. thick. Circular holes (6) are used to represent drains with a variable spacing "L", drain diameter "d" and drain depth "D". The impervious base of the dam is represented by horizontal strips (8). The upstream face (5) has an inclination of 45° to the horizontal and is fed from a tank (3) having an overflow tube (4) to control the effective upstream retained head on the dam. The main supply tank (13) is connected to the feeder tank (3) by a tube (2) and the flowing oil (Supper 7500-20w/50) is controlled by a valve (1). A vertical channel (7) is used to collect the seepage discharge escaped to the toe of the dam. The oil is then collected into a graduated tube (14). A tank (10) receives the excess oil passing through tubes 4 and 9, this oil is lifted again to the main supply tank (13) by a small centrifugal pump (11) through the pipe (12). All experiments are performed at a constant temperature equals 28 c° where the hydraulic conductivity of the soil (K) is calculated.

PROCEDURE OF EXPERIMENTAL WORK.

The experimental procedure is carried out as follow:

1- For constant values of L=45 cm, d=2 cm and D=2cm, the upstream retained head "H" is changed and the corresponding measured values of discharges q_d and q_s are recorded.

2- For the same spacing L=45 cm and drain diameter d=2 cm, drain depth "D" is changed three times to 6 ,10 and 14 cm. For each value of "D", the retained head "H" is changed and the corresponding values of discharges q_d and q_s are also measured.

3- The same experimental procedure in steps 1 and 2 are repeated for different values of spacing = 60, 75 and 90 cm.

4- For each experiment, the free water surface is recorded

5- A total of (114) experimental runs were carried out.

ANALYSIS OF RESULTS

From the experiments which are carried out to study seepage through an earth dam with a pipe drain, design charts are plotted to show the relation between discharge ratio entering the drain (q_d/KH) and upstream retained head ratio (H/L), for values of D/d = 1, 3, 5 and 7.

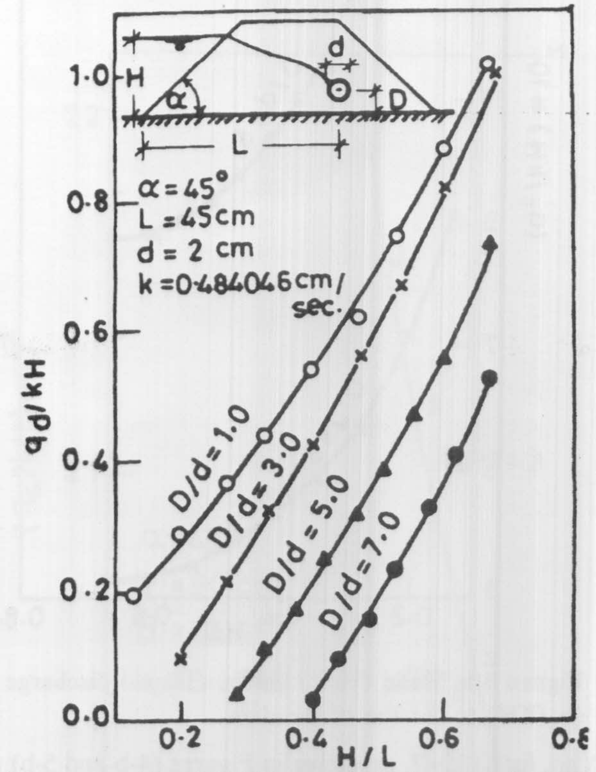

Figure 3-a. Head (H/L) versus discharge (q_d)/KH) for drain.

Figures (3-a, 4-a, 5-a and 6-a) are drawn for constant values of α=45°, d=2 cm and for spacing L=45, 60, 75, and 90 cm respectively. It is clear that discharge ratio (q_d/KH) increases with increasing the retained head (H/L) and also increases with decreasing drain depth ratio (D/d). The relationship shown in Figures (3-b, 4-b, 5-b and 6-b) is drawn between escaped discharge ratio (q_s/KH) and the retained head ratio (H/L) for values of D/d= 3, 5 and 7. As shown in Figure (3-b), for L=45 cm, d=2 cm, D/d= (3 and 5) and $\alpha=45^o$ the escaped discharge ratio decreases with increasing (H/L) while for D/d=7, the escaped discharge ratio decreases with increasing (H/L) up to 0.62 after which the escaped discharge increases.

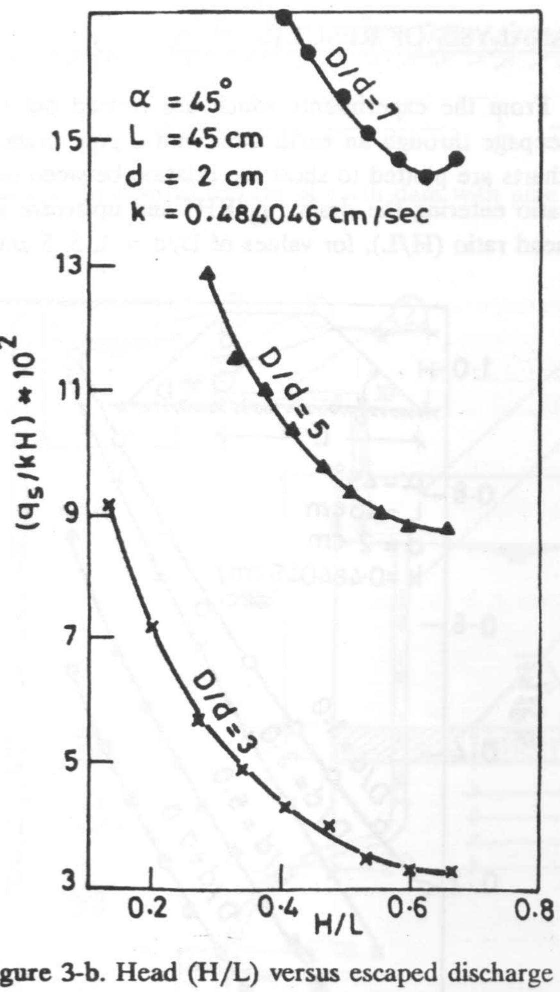

Figure 3-b. Head (H/L) versus escaped discharge (q_s/KH) to the toe of the dam.

Also, for D/d=7, as shown in Figures (4-b and 5-b) the escaped discharge decreases with increasing (H/L) and then starts to increase for values of (H/L) higher than 0.47 and 0.36 for L=60 and 75 cm, respectively. It is also noticed that for high value of D/d = 7, a large quantity of seepage is passed to the toe of the dam, this quantity is reduced when the value of D/d is reduced and disappears for D/d =1.0. Therefore, drain depth measured vertically from the impervious layer must not be more than the drain diameter to prevent the escaped discharge passing to the toe of the dam.

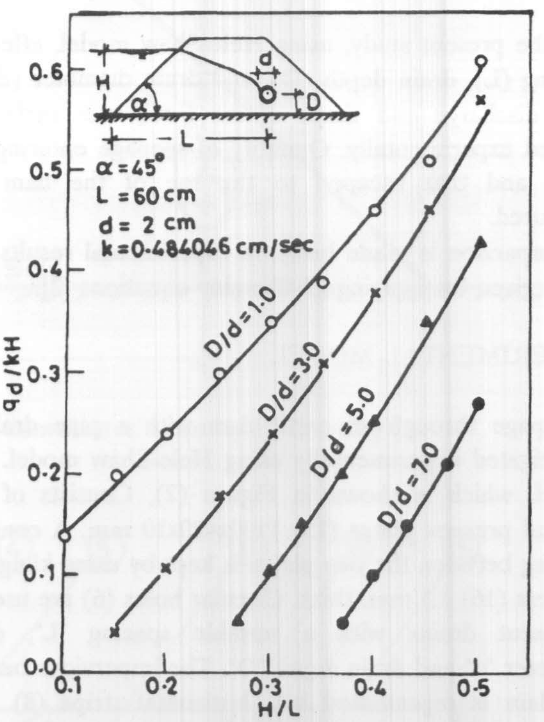

Figure 4-a. Head (H/L) versus discharge (q_d/KH) for drain.

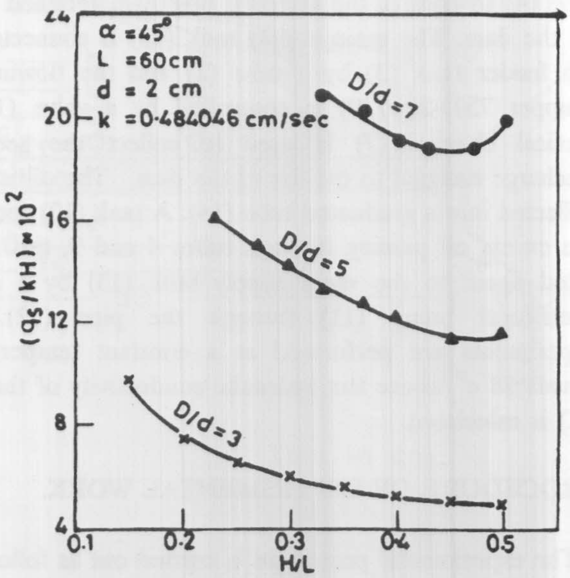

Figure 4-b. Head (H/L) versus escaped discharge (q_s/KH) to the toe of the dam.

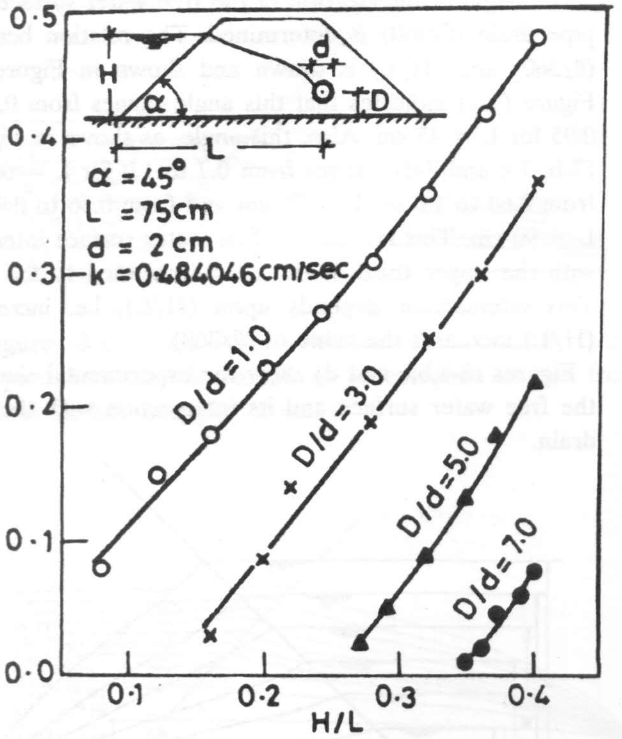

Figure 5-a. Head (H/L) versus discharge (q_d/KH) dor drain.

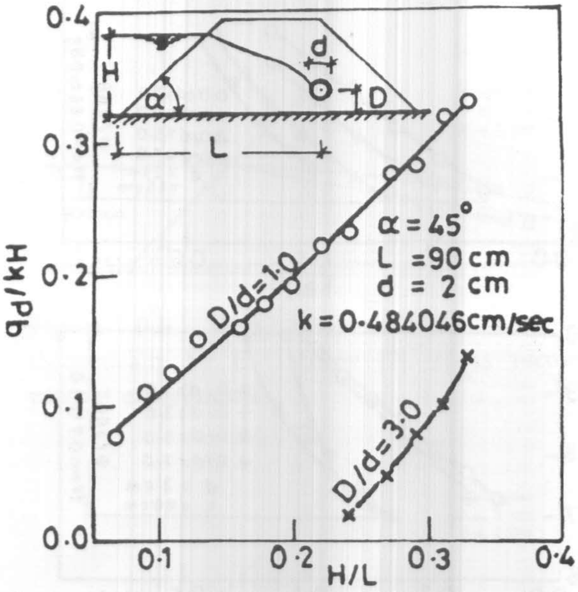

Figure 6-a. Head (H/L) versus discharge (q_d/KH) for drain.

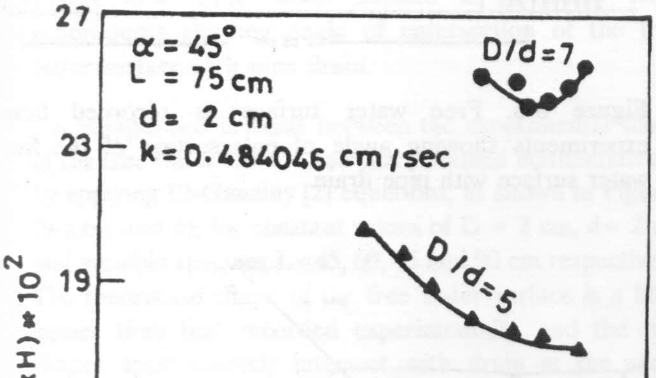

Figure 5-b. Head (H/L) versus escaped discharge (q_s/KH) to the toe of the dam.

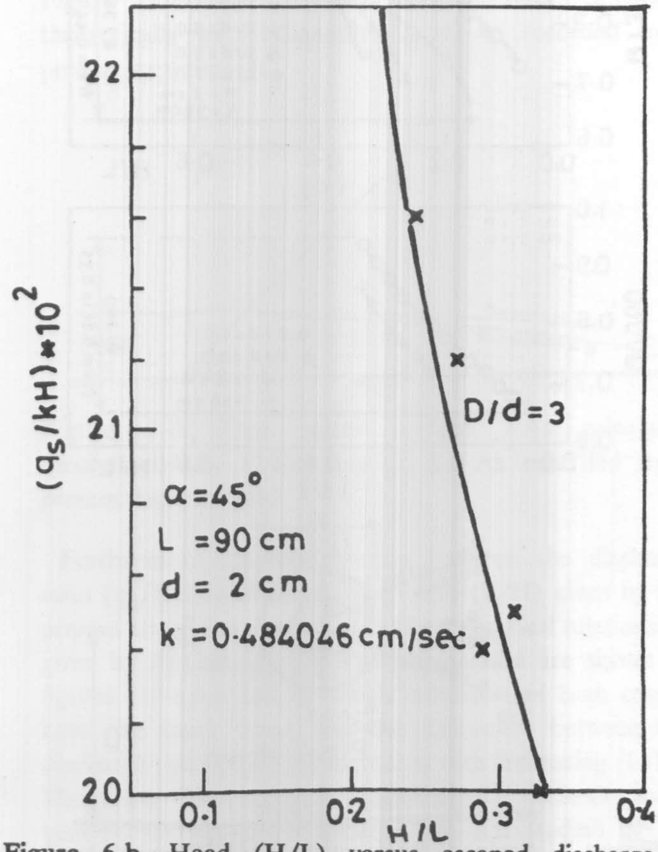

Figure 6-b. Head (H/L) versus escaped discharge (q_s/KH) to the toe of the dam.

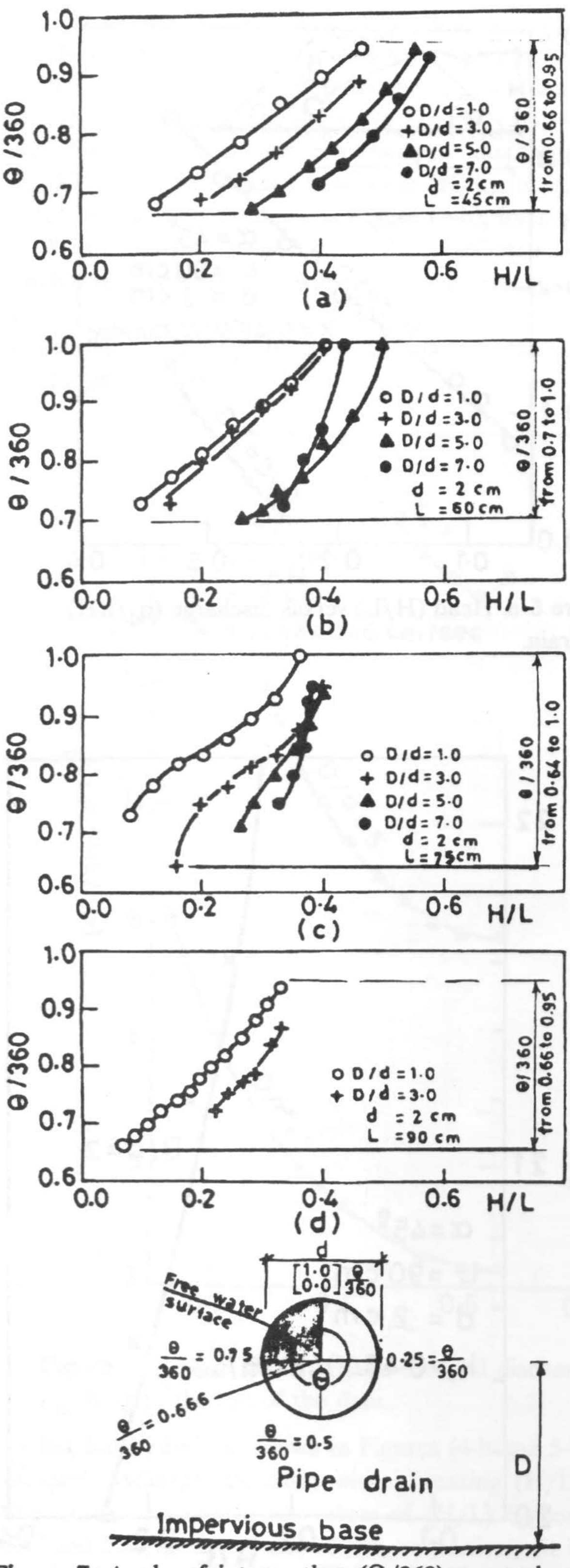

Figure 7. Angle of intersection (Θ/360) versus head (H/L).

The angle of intersection of the free water surface with pipe drain ($\theta/360$) is determined. The relation between ($\theta/360$) and (H/L) is drawn and shown in Figure (7). Figure (7-a) indicates that this angle ranges from 0.66 to 0.95 for L = 45 cm. Also, this angle, as shown in Figures (7-b, 7-c and 7-d), ranges from 0.7 to 1.0 for L = 60 cm, from 0.64 to 1.0 for L = 75 cm and from 0.66 to 0.95 for L = 90 cm. This means that free water surface intersects with the upper third of the drain subjected to the flow. This intersection depends upon (H/L), i.e. increasing (H/L) increases the value of ($\theta/360$).

Figures (8-a,b,c and d) show the experimental shape of the free water surface and its intersection with the pipe drain.

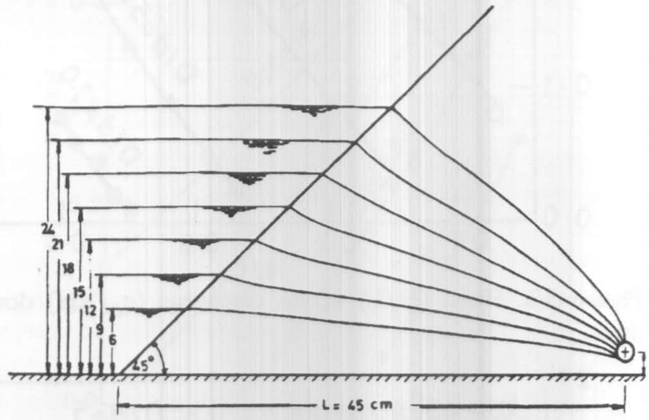

Figure 8-a. Free water surface as recorded from experiments showing angle of entersection of the free water surface with pipe drain.

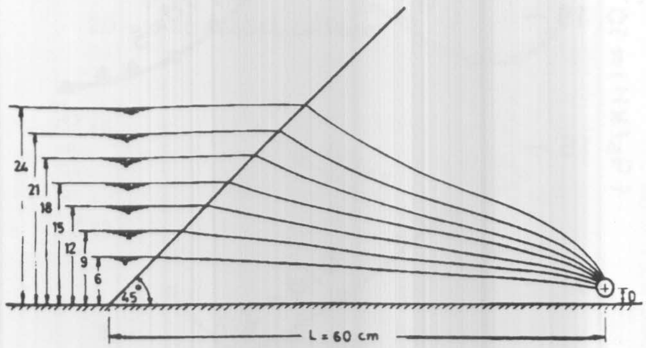

Figure 8-b. Free water surface as recorded from experiments showing angle of entersection of the free water surface with pipe drain.

These shapes ensure that its intersection is located, also, at the upper third of the drain subjected to the flow.

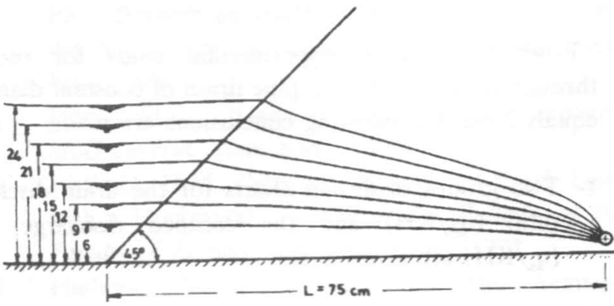

Figure 8-c. Free water surface as recorded from experiments showing angle of entersection of the free water surface with pipe drain.

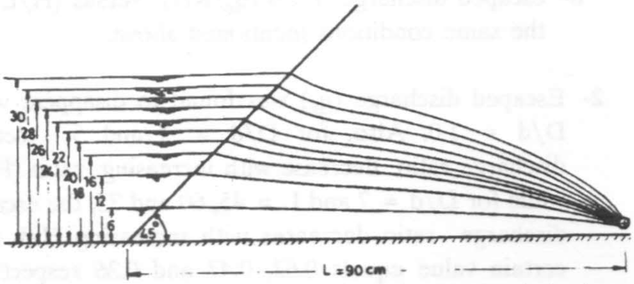

Figure 8-d. Free water surface as recorded from experiments showing angle of entersection of the free water surface with pipe drain.

A comparison is made between the experimental shape of the free water surface and that obtained mathematically by applying El-Ganainy [2] equations, as shown in Figures (9-a,b,c and d), for constant values of D = 2 cm, d= 2 cm and variable spacings L=45, 60, 75 and 90 cm respectively. The theoretical shape of the free water surface is a little higher than that recorded experimentally, and the two shapes approximately intersect with drain at the same zone.

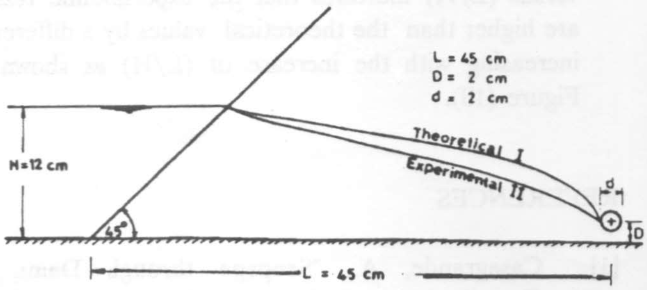

Figure 9-a. Free water surface I-As calculated theoretically by El-Ganainy [2]. II-As recorded from present experiments.

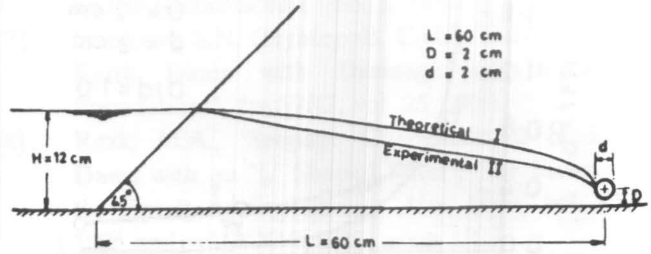

Figure 9-b. Free water surface I-As calculated theoretically by El-Gabainy [2]. II-As recorded from present experiments.

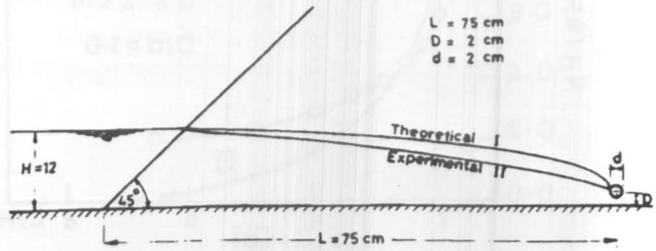

Figure 9-c. Free water surface I-As calculated theoretically by El-Ganainy [2]. II-As recorded from present experiments.

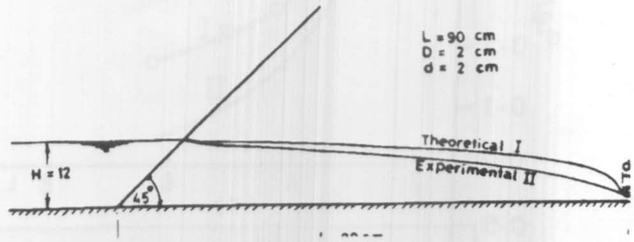

Figure 9-d. Free water surface I-As calculated theoretically by El-Ganainy [2].. II-As recorded from present experiments.

Furthermore, the relationship between the discharge ratio (q_d/KH) and the spacing ratio (L/H) given by the present study is compared with the theoretical relationship given by El-Ganainy [2]. The comparison are shown by figures (10-a,b,c and d) which indicate that both results have the same trend and the difference between the discharge ratio (q_d/KH) increases with increasing (L/H). The above Comparison is made only for drain discharge because the escaped discharge was not studied by El-Ganainy [2].

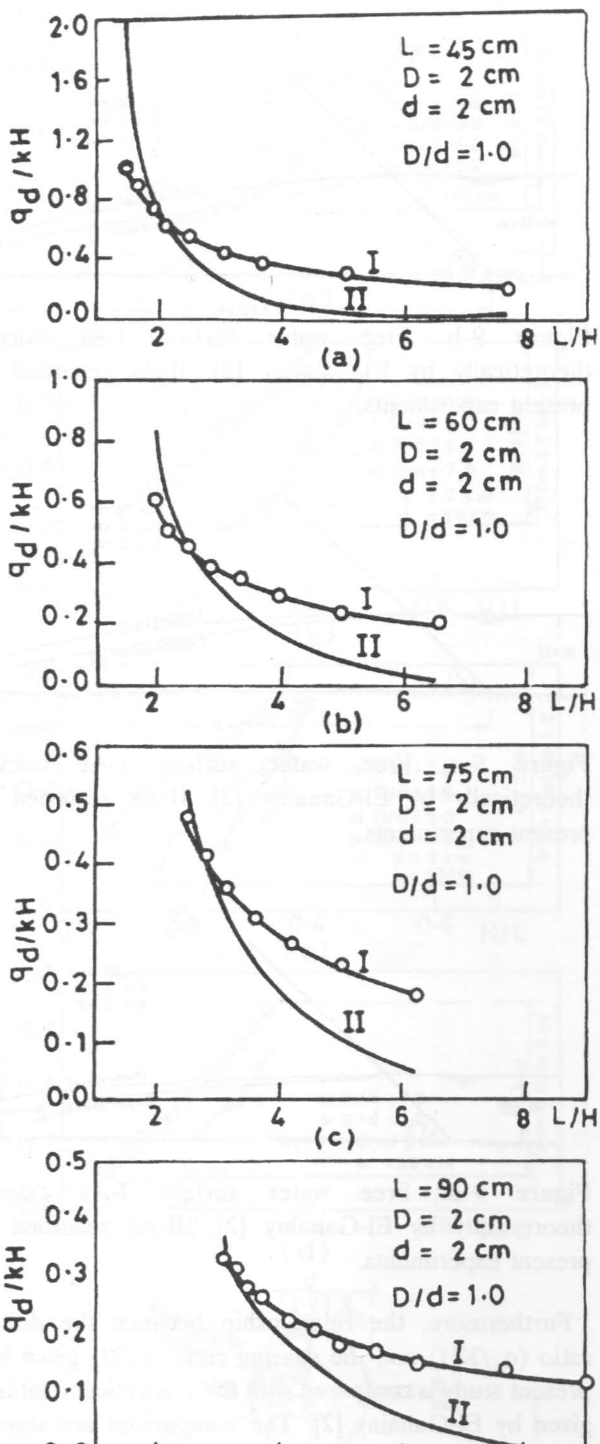

Figure 10. Discharge (q_d/KH) versus spacing (L/H).

CONCLUSION

From the present experimental study for seepage through earth dam with a pipe drain of constant diameter equals 2 cm the following conclusions are made:

1- Two groups of design charts for the drain discharge ratio (q_d/KH) and the escaped discharge ratio (q_s/KH) are given as follows:

a- drain discharge ratio (q_d/KH) versus (H/L) are plotted for different values of D/d = 1, 3, 5 and 7. These charts are shown for four different spacings L = 45, 60, 75 and 90 cm.

b- escaped discharge ratio (q_s/KH) versus (H/L) for the same conditions mentioned above.

2- Escaped discharge (q_s) was found to disappear when D/d = 1.0. Also, for D/d = 3 and 5 escaped discharge ratio decrease with increasing ratio (H/L) while for D/d = 7 and L = 45, 60 and 75, the escaped discharge ratio decreases with increasing H/L to a certain value equals 0.62, 0.47 and 0.36 respectively after which the discharge ratio increases.

3- Angle of intersection of the free water surface with pipe drain (θ/360) is plotted versus (H/L) and for most experimental cases the free water surface intersects with the upper third of the drain subjected to the flow.

4- A comparison between experimental shape of the free water surface and that obtained by applying El-Ganainy theoretical equations [2] is made. Theoretical shape has slightly higher values than those recorded experimentally. Also, the comparison between (q_d/KH) versus (L/H) indicates that the experimental results are higher than the theoretical values by a difference increasing with the increase of (L/H) as shown in Figure (10).

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