SEEPAGE CHARACTERISTICS BENEATH TAIL ESCAPE STRUCTURES HAVING FLAT FLOORS WITHOUT SHEETPILES

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ABSTRACT

The configurations of the downstream seepage face behind tail escape structures has an effect on the characteristics of seepage beneath floors of such structures. Experiments showed that, the seepage flow partially separates from the under-side of the floor, depending on many variables. In the present study, both the length of the horizontal seepage face behind the floor S and the variation of the upstream and downstream water levels were taken as variables to be investigated, since they have an effect on the seepage characteristics for this case (seepage quantity, uplift pressures and the separation of flow from the floor). Experiments were conducted using the Hele-Shaw model with motor's oil as a viscous flow. Charts and curves, describing the effect of the distance S and the depths H_1, H_2 and H on the seepage characteristics, are presented.

NOTATIONS

b	Distance between the two prespex sheets of the model,
g	Gravity acceleration,
H	Difference between the upstream and downstream water levels,
H_1	Depth of flow at the upstream side,
H_2	The free board of the drain,
h	Potential at any point along the floor,
k	Hydraulic conductivity = $g\, b^2/12\nu$ cm/sec^2,
L	Length of the floor,
ℓ	Unseparated length of the floor from the flow,
q	Quantity of seepage per unit width,
S	Horizontal distance of the downstream seepage face behind the floor,
T_1,T_2	Thicknesses of the permeable foundation,
t	Depression depth of the floor in the permeable foundation,
x	Fractional distance of the floor length,
ν	Kinematic viscosity of the oil cm^2/sec.

1. INTRODUCTION

Tail escape structures are commonly used for escaping the excess discharges of irrigation canals into drains. They are constructed at the canal ends just before the junction either to the drain or to any depression in the area. Tail escape structures may be constructed in the form of regulator or weir, which is governed by many considerations.

The floor of tail escape structures may be founded on permeable foundation through which the seepage flow occurs. The seepage flow affects the structure through three parameters; the uplift pressures, the seepage quantity and the exit gradients.

Tail escape structures are characterized by the discrepancy of the upstream and downstream seepage faces. The downstream seepage face for tail escape structures is shaped to accommodate the drain path, which presents a seepage problem with boundary conditions differ from other hydraulic structures. The study of the effect of the configurated downstream seepage face on the seepage characteristics beneath tail escape structures leads to an economic design for such structures. The seepage characteristics, for many seepage problems, concerned with the same conditions for the upstream and downstream seepage faces have been extensively studied on different ways of approach [1,2,3,4]. However, the effect of the shaped downstream seepage face on the seepage characteristics beneath tail escape structures has not been dealt with.

Figure (1) shows a plan and a section along the floor for a tail escape regulator, constructed at the end of a canal with a crossing drain. In the present study, the experiments showed that, the seepage flow separates from the under-side of floor depending on the upstream and downstream water levels and the horizontal distance behind the floor S, as demonstrated in Figure (1). The horizontal distance S may be ascendingly extended from the drain, creating an approaching distance for the canal flow to the drain.

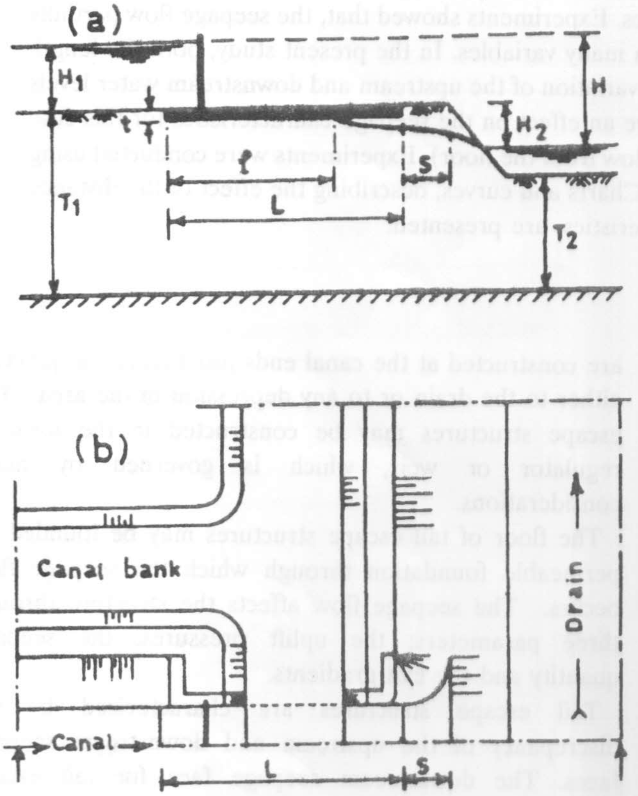

Figure 1. Definition sketches;
a) long. sec along the floor,
b) half plan.

The present study is intended to investigate experimentally the effect of the shaped downstream seepage face on the seepage characteristics beneath a tail escape structure. The influence of the downstream seepage face, on the seepage characteristics, depends on the floor length L, the depths of the permeable foundation T_1 and T_2, the thickness of floor t, the distance S, the slope of the inclined downstream seepage face and the depths H_1, H_2 and H. Keeping L, T_1, T_2, t and the slope as constant values, H_1, H_2, H and S were taken as variable parameters, causing the higher effect on the following; separation of flow from the floor, the uplift pressures along the floor and the seepage quantity.

2. EXPERIMENTAL PROCEDURE

The characteristics of seepage beneath tail escape structures having floors without sheetpiles are studied experimentally using the Hele-Show model. The model was prepared to satisfy the conditions recommended in Ref. [5] to eliminate the effect of the impervious ends of the model.

Figure (2) shows the model arrangements,which consists of two vertical prespex sheets (1) each of 1320 X 800 X 10 mm. The two sheets are kept 1.5 mm. apart using Klingarite sheet (2). The floor model (3)is formed from the same Klingarite sheet. The length of the floor L was taken equal to 10 cms. The depression depth of the floor model t equals to 0.5 cm. representing a ratio of t/L equals to 5%. The downstream seepage face was formed by lowering it through a slope of 1:1. The upstream seepage face is fed by oil from elevated tank (4). The upstream and downstream sides are provided with tanks (5) and (6) with over flow tubes (7) and (8) To maintain constant levels at the two sides. These tubes could be moved vertically to change the elevation of the flow surface to the required level in each side. The overflowing discharge from the downstream tube is measured using measuring cylinder (9) to measure the seepage quantity. The overflowing oil from the tubes is collected in tank (10), from which, oil is pumped to the elevated tank by pump (11). The motor's oil super 7500-20 W 150 is considered as the viscous flow to be flowed through the width b between the two prespex sheets (b = 1.5 mm). Pressures under the floor are measured by piezometers (12), which are made by slotting the model at a fractional distances of the floor length. Each slot is 2 mm. wide. To eliminate the surface tension effect, the flow at the upstream and downstream sides was initially maintained at the same level. Then, the heights of oil in the piezometers due to surface tension were measured to be abstracted from any further measurements of pressures. The experiments are conducted by varying the horizontal distance "S" behind the floor as a ratio of the floor length L, The values of S/L were taken equal to 0.0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, and 1.4. For each of the above values of S/L, the depths H_1, H_2 and H are changed as a ratio of the floor length L.

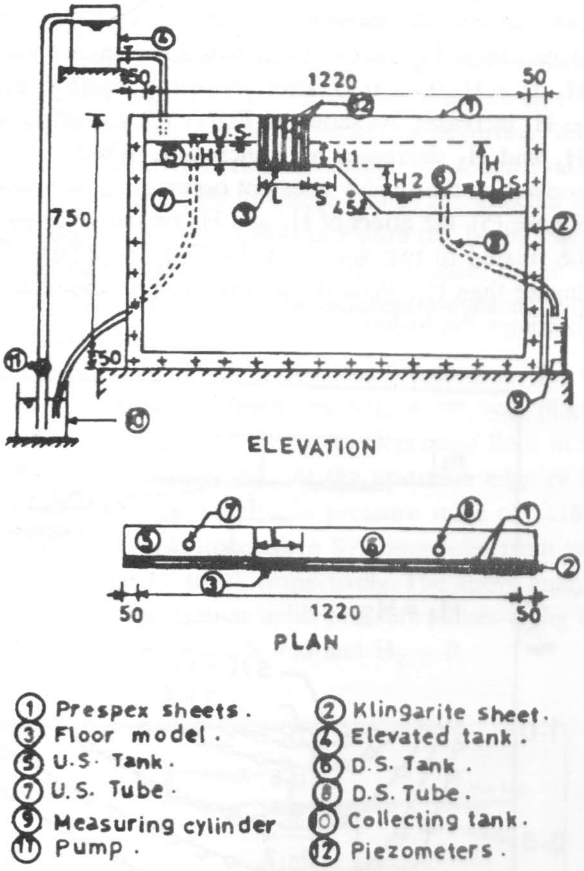

Figure 2. Experimental model (dim.in mm).

3. ANALYSIS OF RESULTS

The experimental results showed that, the shape of the downstream seepage face have a noticeable influence on the seepage characteristics beneath floors of tail escape structures. This effect essentially depends on both the horizontal distance behind the floors and the variation of the upstream and downstream flow levels, which would be discussed in the following analysis of the experimental results.

3.1 *Separation of the Seepage Flow From the Under-Side of the Floor*

The experiments showed that, the flow separates from the under-side of the floor, creating free seepage zone beneath the floor. This separation depends on the values of depth H_1, depth H_2, horizontal distance S and the floor thickness t. The floor thickness was kept constant with a minimum value as possible ($t = 0.05$ L). The experiments were carried out according to the following three approaches:

In the first approach, the upstream depth H_1 was taken of constant value equals to 0.5 L, while the downstream level was gradually lowered to increase H_2 from zero to 1.5 L with equal increments each of 0.125 L. The unseparated length ℓ under the floor was measured and plotted against the depth H_2 as presented in Figure (3). The figure shows that, the separated length of floor ($L-\ell$) increases as the depth H_2 increases, while it decreases as the distance S increases. For $S/L \leq 0.6$, the separated length rapidly increases as H_2 increases until $H_2/L = 1.0$, after which it slowly increases. When $H_2/L \geq 1.5$, the effect of H_2 on the separation of flow becomes negligible. For $S/L > 0.6$, the separated length slowly increases as H_2 increases. As S/L increases, the separation occurs only for high values of H_2 until $S/L = 1.2$, the separation completely diminishes.

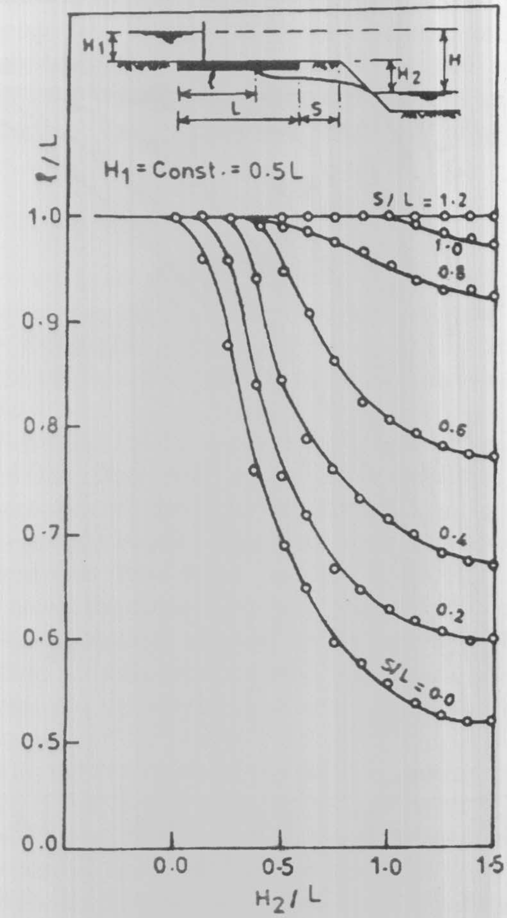

Figure 3. Variation of the unseparated length of floor with variation of H_2 for constant value of H_1 =0.5L.

In the second approach, the depth H_2 was kept constant value equals to 0.5 L, while the upstream depth H_1 was increased with a relative value H_1/L ranging from zero to 1.0. As shown in Figure (4), the separated length decreases as H_1 increases, however this effect decreases as S/L increases. For S/L > 0.6, the separation occurs only at small values oh H_1. For S/L > 1.5, nearly there is no separation even for very small values of H_1.

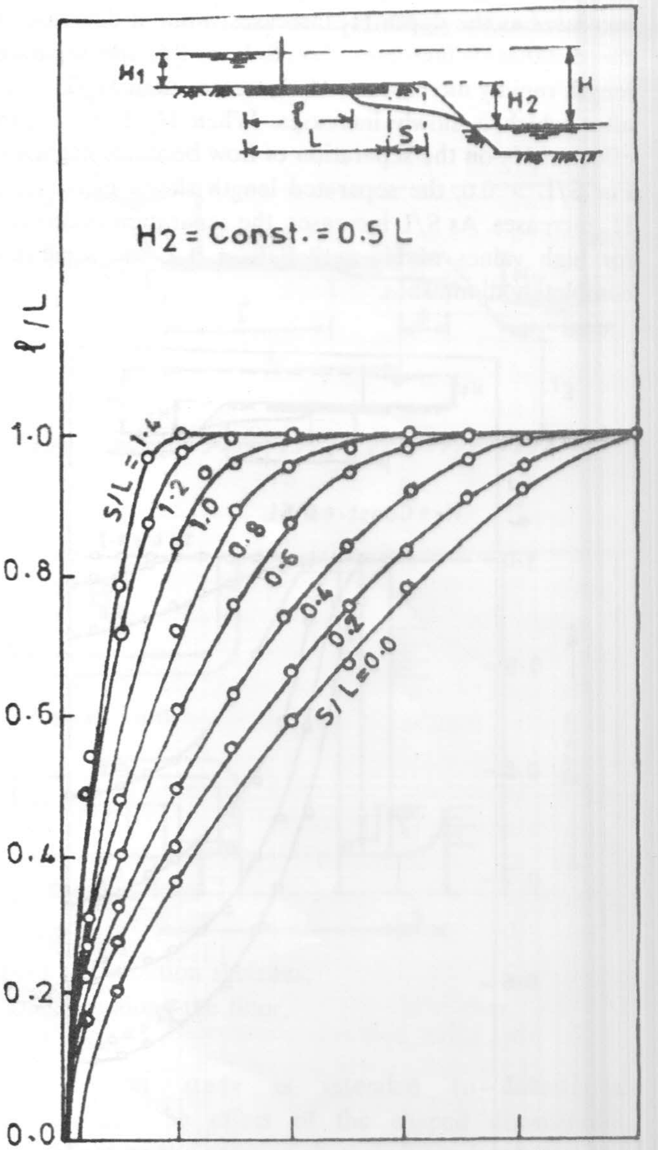

Figure 4. Variation of the unseparated length of floor with variation of H_1 for constant value of H_2 =0.5L.

In the third approach, both the two depths H_1 and H_2 are equally increased with a relative values of H_1/L = H_2/L vary from zero to 1.0. As presented in Figure (5), the experiments showed that, the unseparated length decreases as H_2 increases reaching a minimum value when H_1/L = H_2/L = 0.35, after which the length ℓ increases as H_1 increases. As shown in Figure (5), the effect of both H_1 and H_2 decreases as S increases. When S/L = 1.0, separation thoroughly does not occur. As demonstrated in Figure (5), the effect of H_1 and H_2 on the separation may be related to two zones; in the first, the effect of H_2 is higher than H_1, while in the second zone, the effect of H_1 becomes the higher.

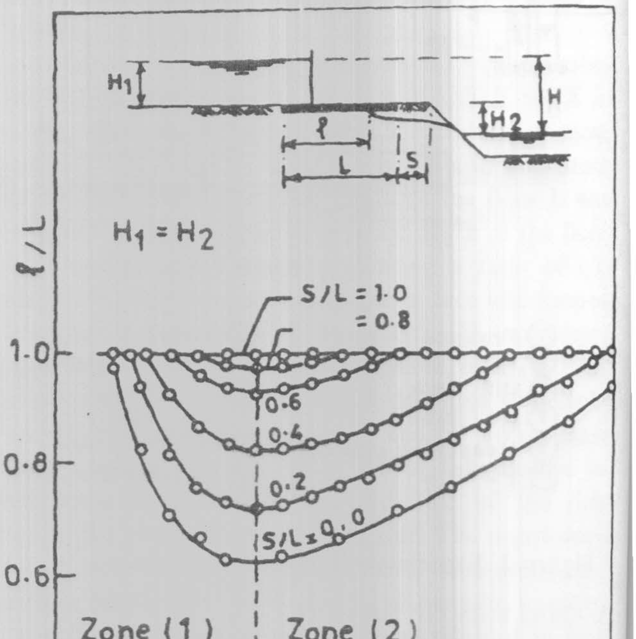

Figure 5. Variation of the unseparated length of floor with variation of both H_1 and H_2.

3.2. Uplift Pressures Along the Floor

In this study, the upstream depth H_1 was kept constant, equals to 0.5 L, while H_2 varies from zero to 1.5 L. The experimental results showed that, the values of the uplift pressure along the floor decrease as H_2/L increases with decreasing rate. For values of H_2/L range from 0.0 to 0.5 a considerable reduction in the pressure values is obtained. For values of H_2/L vary between 0.5 to 1.0, a poor effect of H_2 on the pressures is occurred. When $H_2/L > 1.0$, nearly, there is no change in pressure values. On the other hand, the pressure values are affected also by the distance S as presented in Figure (6). In the Figure, the maximum values of the uplift pressure, which are obtained when $H_2 = 0.0$ for different values of S, are plotted along the floor length L. It is seen from the Figure that, the pressure values increase as S increases. In the Figure the curve, defined by $S/L = \infty$, was plotted according to Povlovsky's theory for depressed floor in the permeable foundations [6]. At the upstream edge of the floor ($x/L = 0$), an increase in pressure value of 0.18 H and 0.06 H are obtained when S/L increased from zero to 1.0 and from 1.0 to ∞, respectively. The above analysis shows that, the minimum uplift pressure values along the floor are obtained when $S = 0$ and $H_2 = 0$.

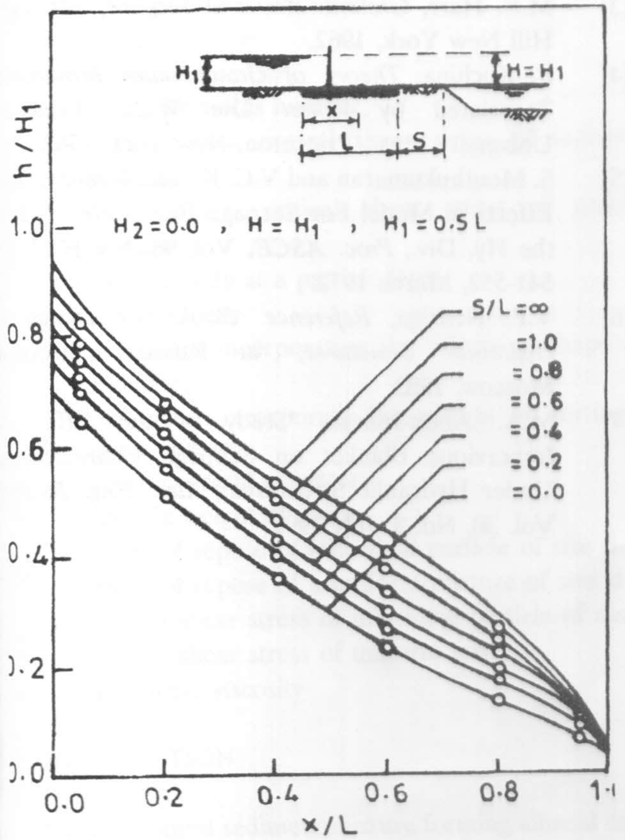

Figure 6. Variation of the maximum uplift pressures along the floor with the variation of S.

3.3. Seepage Quantity

The experimental results showed that, the variation of both the total head H ($H = H_1 + H_2$) and the horizontal distance S have a remarkable effect on the seepage quantity. For constants values of H_1 equals to 0.5 L, the relative value H/L varies from zero to 2.0. The results are presented in Figure (7), from which it is clear that, the seepage quantity rapidly increases as H increases until $H/L = 1.0$, then a slowly increase occurs. When $H/L = 2.0$, the quantity of seepage nearly becomes constant whatever the value of H. Increasing the distance S, a reduction in the seepage quantity is obtained, however this reduction decreases as S increases. The values of seepage quantity obtained when $H = H_1$, ($H_2 = 0$), are plotted versus the relative distance S/L as shown in Figure (8). The Figure shows a rapid decrease in seepage quantity until $S/L = 1.0$, after which the reduction becomes very small as S increases. The value of q/kH_1, which corresponds to $S/L = 6$, was found to be 1.07 [7]. Referring to Figure (8), the values of q/kH_1 corresponding to $S/L = 0$ and 1.2 are 1.66 and 1.15, respectively, which present an increase of 55% and 7% in the seepage quantity compared with value of q/kH_1 for $S/L = 6.0$.

4. CONCLUSIONS

From the analysis of the experimental results, it can be concluded that, the shape of the downstream seepage face has a remarkable effect on the seepage characteristics beneath tail escape structures, which may be summarized as follows :

1- Separation of the seepage flow from the under-side of the floor may occur. The separation length increases as the drain free board increases. The separated length of the floor decreases as both the upstream flow depth and the horizontal distance behind the floor increase. Separation of seepage flow is strongly affected by the upstream depth of flow. Separation nearly disappears when the distance, behind the floor, equals 1.5 times the floor length.

2- The uplift pressure along the floor decreases as the drain free board increases, while it increases as the horizontal distance behind the floor increases. The values of the uplift pressure along the floor are the highest when the drain free board equals to zero. The uplift pressure has not been affected nearly when the horizontal distance, behind the floor, is greater than the floor length.

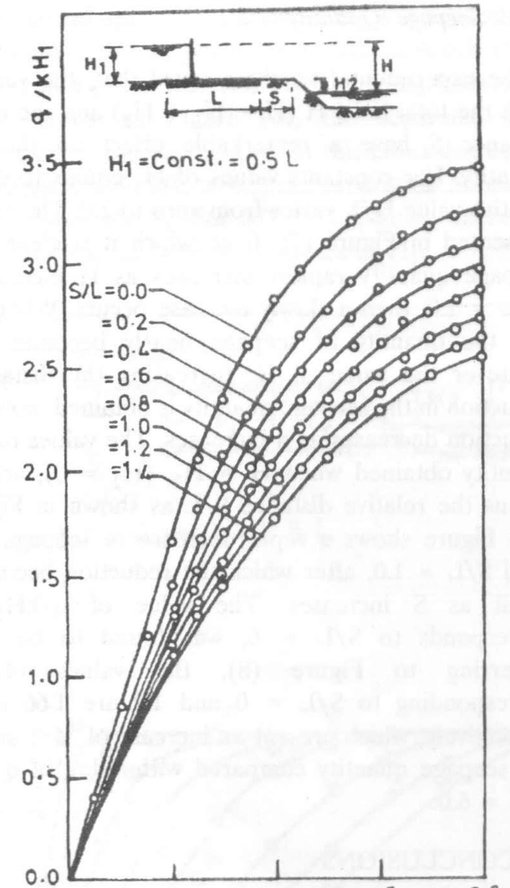

Figure 7. Variation of seepage quantity with H/L for different values of S/L.

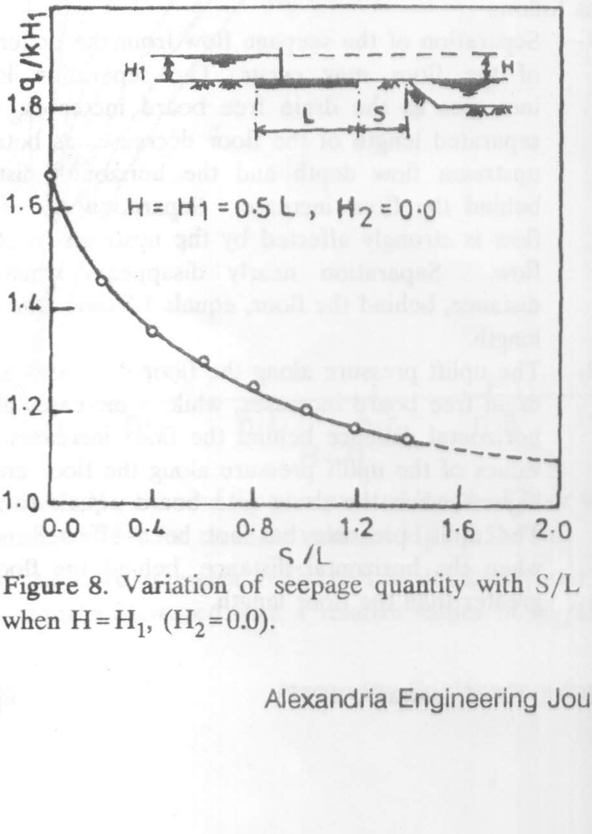

Figure 8. Variation of seepage quantity with S/L when $H=H_1$, $(H_2=0.0)$.

3- Seepage quantities increase when the drain fre board increases. When the horizontal distance behind the floor, increases the seepage quantitie decrease. For a zero value of the drain free board the quantity of seepage becomes nearly constan when the horizontal distance exceeds 1.5 times th floor length.

Finally, for storage structures (dams) which are followe by depressions, it is preferable to be constructed at distance, from the depression, nearly equals to 1.5 times the base width at least. For weirs and regulators, it i advisable to be constructed closer to the junction a possible, if provided with an end sheetpile.

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