HEIGHT OF THE HORIZONTAL FILTER IN EARTH DAMS BASED ON AN IMPERVIOUS BASE

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ABSTRACT

An experimental study is carried out to evaluate the height of the horizontal filter in earth dams based on an impervious base. Height of the filter is recommended as a relative value of its distance measured from the heel of the dam to the beginning of the filter. Also filter's height can be estimated as a relative value of the dam height. The maximum length of intersection of the free water surface with the horizontal filter is obtained. Parameters affecting on the seepage discharge entering the filter, such as, height of the filter, spacing of the filter and the upstream retained water depth, are studied.

NOTATION

- F height of the filter,
- h height of the free water surface, measured from the impervious base, at the beginning of the filter,
- H the upstream retained water depth,
- k permeability coefficient,
- l length of the horizontal intersection of the free water surface with the horizontal filter,
- L spacing of the filter, measured from the heel of the dam to the beginning of the filter,
- Q the seepage discharge entering the filter,
- T the total height of the dam, and
- α angle of inclination of the upstream face of the dam, (α = 45°).

INTRODUCTION

The problem of earth dam with horizontal filter, was mathematically studied by Hathoot [4]. The Case of a dam on an impervious base, has been studied experimentally in this paper. Hathoot derived the discharge formula and established equation of the free water surface which is plotted and put in comparison with that plotted one according to Numerov [7]. Fathi Abdrabbo [2] used the direct boundary element method for finding the position of the entire line of seepage, the position of exit point of the line of seepage and the rate of seepage for steady flow through isotropic earth dam with horizontal filter. The same problem was studied before by Casagrande [1] and Kozeny [5].

Height of the horizontal filter was not taken into consideration in the above mentioned works. The aim of the present experimental study is to investigate the required height of the horizontal filter and its spacing. Also it is required the maximum length of intersection of the free water surface with the horizontal filter.

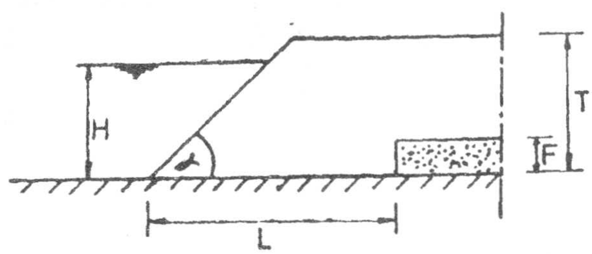


Figure 1. Geolgical section

SAND MODEL

A sand model, Figure (2), is used to perform the experimental runs on an earth dam with horizontal filter. The grain size distribution of the used sand is shown in Figure (3). The mean diameter of the sand equals 1 mm and has permeability coefficient equals 0.04 cm/sec at wet density which is equal to 1.47 gm/cm^3. The front face of the dam is represented by a perforated steel plate (5), which has an inclination (α=45°) to the horizontal, and is covered with a synthetic material. The synthetic material allows water easily to seepage through the sand. The sand (6) is put in the sand box almost by the same manner in each experiment so, permeability of the sand does not change. The filter (7) is fabricated from a perforated steel plate, and is covered with the same synthetic material used in the upstream face of the dam. The seepage discharge entering the filter passes through a hole (8) located at the box bottom, and is measured by a graduated tube (9). A main tank (1) is used to supply water through feeder tube (2) to the model, and water is controlled by a value (3). The overflow (10) is used to fix the required head in the feeder (4). The head is kept constant in the main tank (1) an overflow tube (10). Seventeen piezometers constructed and distributed along the front face of model to record the free water surface.

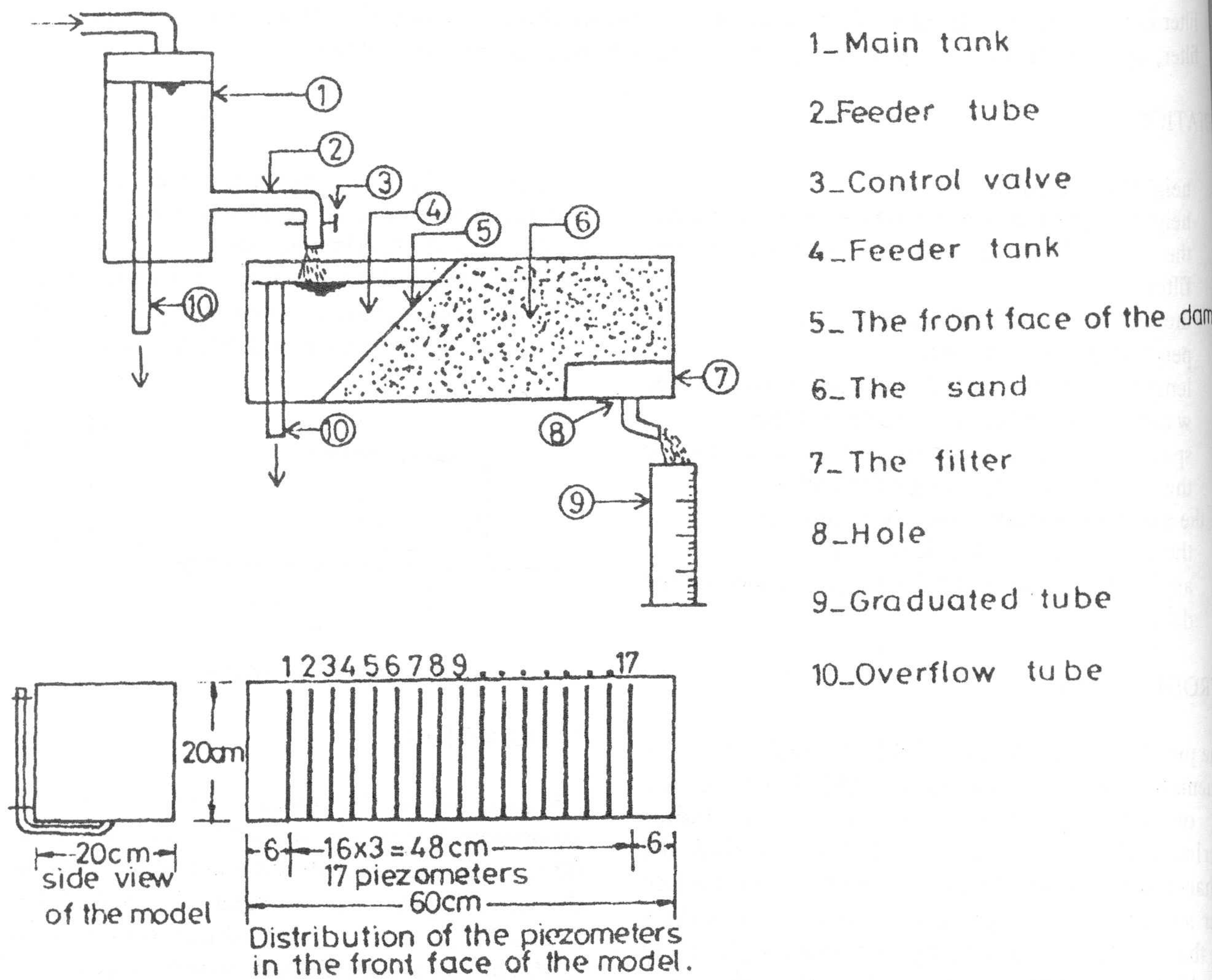


Figure 2. Sand model.

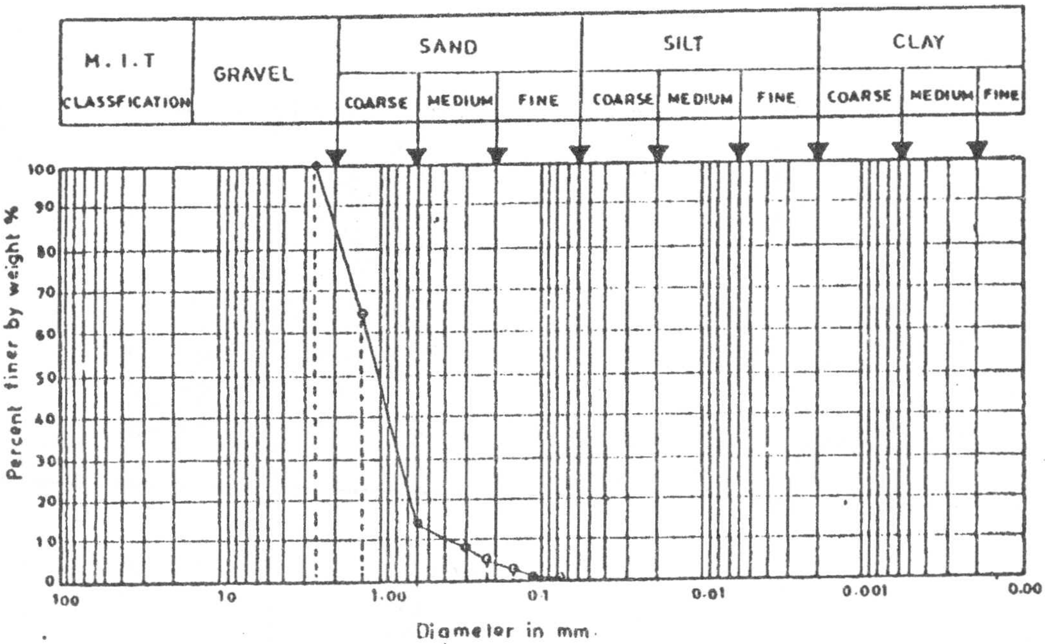


Figure 3. Grain size distribution of the used sand d_{50} = 1.0 cm and k=0.04 cm/sec at γ=1.47 gm/cm^3.

PROCEDURE OF EXPERIMENTS AND PARAMETERS TESTED

1- For a constant spacing (L), height of the filter (F), and head of water (H), the seepage discharge to the filter is measured and the free water surface is recorded using piezometers.
2- The retained upstream water depth is changed, and step No. 1 is repeated.
3- The spacing (L) is changed and steps 1 and 2 are repeated.
4- For a constant spacing, effect of the filter height is studied by changing it several times. In each experiment, steps 1 and 2 are carried out.

ANALYSIS OF RESULTS

An experimental study is carried out using a sand model to estimate the minimum required height of the horizontal filter constructed in an earth dam based on an impervious base. Free water surface in each experiment is recorded and drawn at the beginning of the horizontal filter, Figure (4). The free water surface is analized and both of its height (h) at the beginning of the filter and its intersection with the filter to the horizontal (ℓ) are measured and recorded in Table (1). Figure (5) shows the relationship between the relative height of the filter (F/L) versus the relative height of the free water surface at the beginning of the filter (h/H) for H/T ranging from 0.21 to 0.95. It is clear that, the relative height of the free water surfaces (h/H) increases with increasing the relative height of the filter (F/L), and reaches a maximum value at F/L = 0.12, after which (h/H) decreases. It means that, the required height of the horizontal filter "F" in the case study may be taken about "0.12" of the spacing of the filter, (F = 0.12 L). Figure (6) explains the relationship between the relative height of the filter (F/L) and the horizontal relative intersection of the free water surface with the filter (ℓ/F). From Figure (6), for the relative height of the retained upstream water depth (H/T) which ranges from 0.84 to 0.95 at F/L = 0.12, the free water surface intersects with the filter at its beginning, where ℓ/F = 0.0. It has a maximum length of intersection (ℓ/F) which equals 1.15 at F/L = 0.04. The values of the maximum length of intersection (ℓ/F) appear at F/L= 0.04. For H/T = 0.74, 0.63 and for H/T ranging from 0.53 to 0.21, the maximum value of (ℓ/F) equals 1.0, 0.8 and 0.5 respectively.

The relationship between the relative height of the filter (F/T)and(h/H), for different values of (H/L) ranging from 0.16 to 0.72, is shown in Figure (7). In the case study, the relative height of the horizontal filter also can be estimated as 0.16 of the total height of the dam.

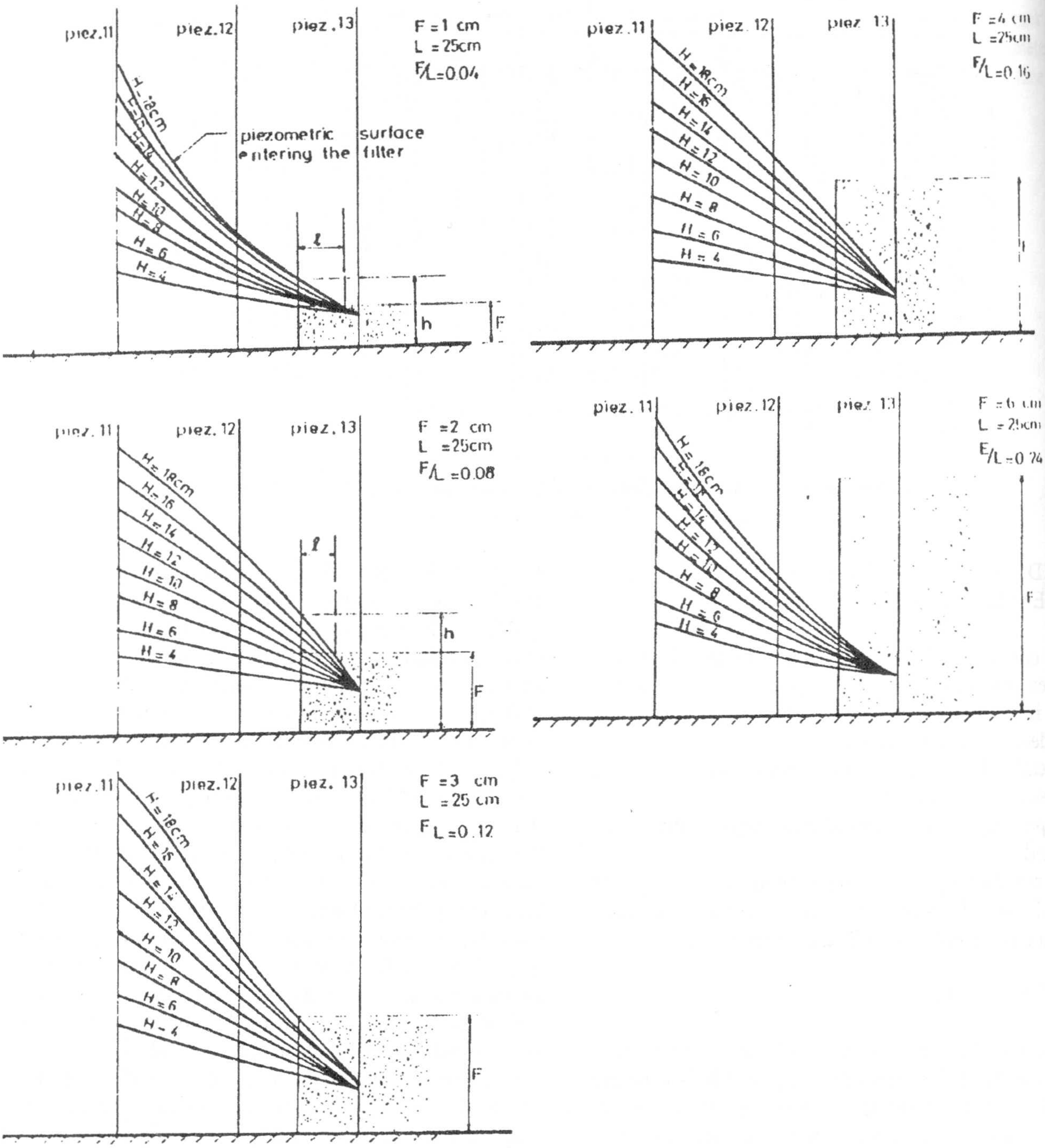
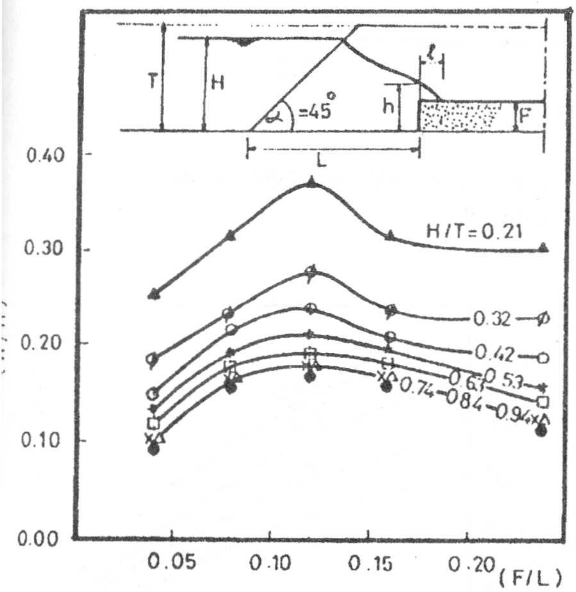


Figure 4. Intersection of the free water surface with the filter.

Table 1.

F/L = 0.04		F/L = 0.08		F/L = 0.12		F/L = 0.16		F/L = 0.24	
h/H	ℓ/F	h/H	ℓ/F	h/H	ℓ/F	h/H	ℓ/F	h/H	ℓ/F
0.097	1.15	0.166	0.425	0.167	0.0	0.161	0.0	0.117	0.0
0.100	1.15	0,169	0.325	0.169	0.0	0.163	0.0	0.119	0.0
0.100	1.00	0.171	0.250	0.179	0.0	0.171	0.0	0.129	0.0
0.108	0.80	0.183	0.00	0.192	0.0	0.183	0.0	0.142	0.0
0.125	0.50	0.190	0.00	0.210	0.0	0.190	0.0	0.160	0.0
0.144	0.50	0.219	0.00	0.238	0.0	0.200	0.0	0.188	0.0
0.183	0.50	0.267	0.00	0.283	0.0	0.233	0.0	0.225	0.0
0.250	0.00	0.313	0.00	0.375	0.0	0.313	0.0	0.300	0.0



gure 5. The relative height of the filter (F/L) versus relative height of the free water surface (h/H) at the ginning of the filter.

ample

iven: the total height of the dam T = 5.5 m for maximum retained water depth H = 5.0 m

equired: height of the filter F and its spacing L

olution: to find height of the filter, substitute in the term F/T = 0.16 ∴ F = 0.88 m spacing of the filter L is given from the term $F/L=0.12 \therefore L=\frac{0.88}{0.12}=7.33$ m

It can be said that F ≃ 0.9 m and L = 7.35 m for the values of the upstream angle of inclination which equals 45°.

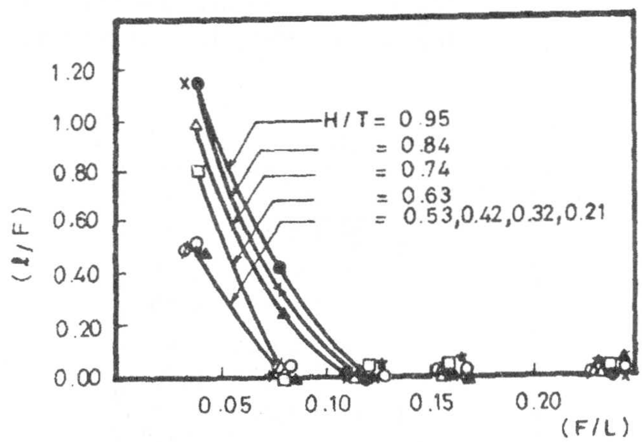


Figure 6. The relative height of the filter (F/L) versus the relative horizontal intersection of the free water surface (ℓ/F) with the filter.

Table (2) indicates some results of the height (F) and spacing (L) of the horizontal filter, constructed in earth dams, for different values of the dam height (T) and the maximum upstream retained water depth (H). The angle of the upstream face of the dam is constant and equals 45°.

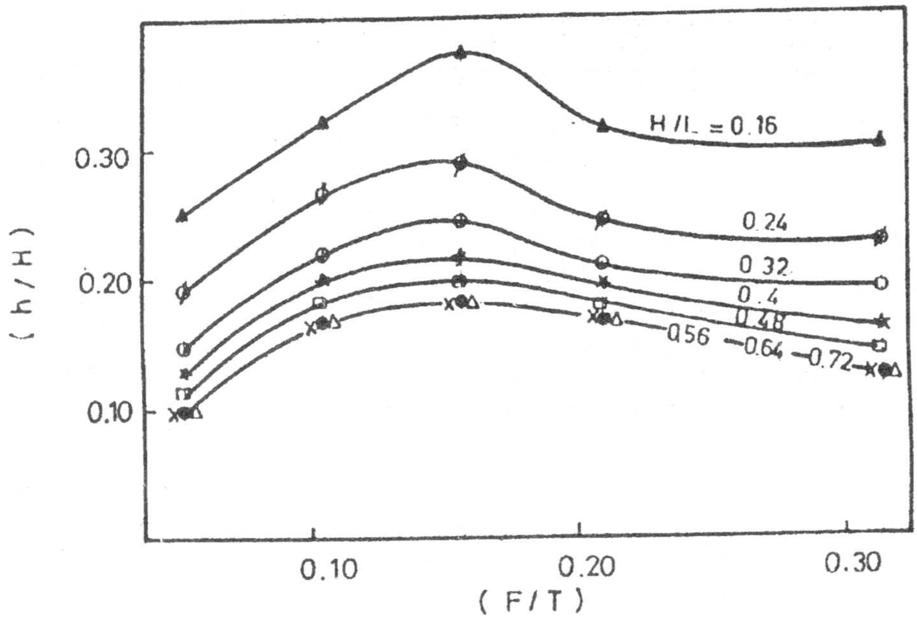


Figure 7. The relative height of the filter (F/T) versus the relative height of the free water surface (h/H) at the beginning of the filter.

Table 2.

max H_m	T_m	F_m	L_m
1	1.25	0.20	1.70
2	2.25	0.35	2.95
3	3.50	0.50	4.20
4	4.50	0.65	5.45
5	5.50	0.80	6.70
6	7	1.00	8.35
7	8	1.15	9.60
8	9	1.30	10.85

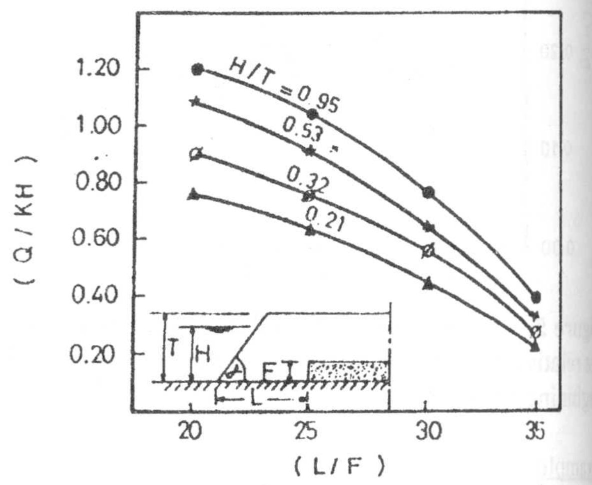


Figure 8. Spacing (L/F) versus discharge (Q/KH).

Figure (8) is plotted showing the relationship between spacing of the filter (L/F) and the seepage discharge to the filter (Q/KH), for (H/T) ranges from 0.21 to 0.95. It is shown that the discharge decreases with increasing the spacing.

A comparison between experimental discharge (Q/KH) and that given by Hathoot [4] is made, as shown in Figure (9) and recorded in table (3).

Table 3.

H/T	L/T	(Q/KH)	
		Experiments	Hathoot [4]
0.95	1.05	1.16	1.086
	1.32	1.04	0.832
	1.58	0.74	0.665
	1.84	0.37	0.549

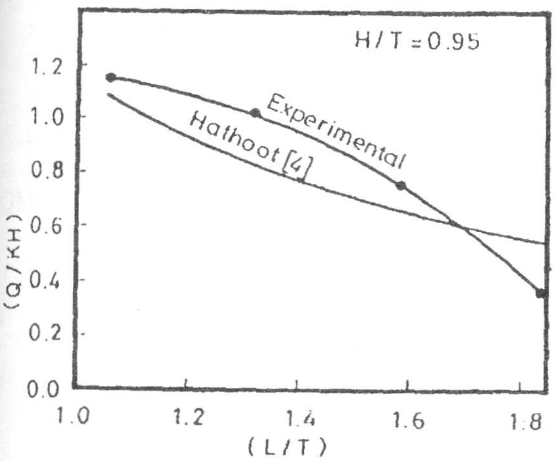


Figure 9. Comparison between discharge given by Hathoot [4] and that measured from experiments.

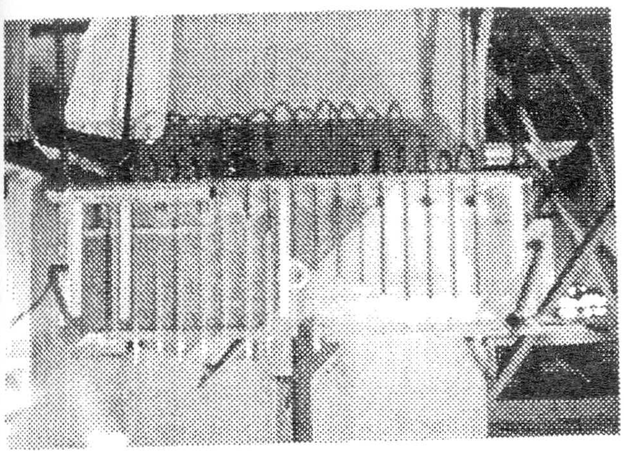


Photo (1).

The difference between experimental results and theoretical one, given by Hathoot, ranges from 6 to 20% for (L/T) < 1.6. This difference increases with increasing (L/T). The two results of (Q/KH) are equal at L/T = 1.7.

A Sample of the photographed free water surface is shown in Photo (1).

CONCLUSIONS

From the previous analysis of an earth dam, based on an impervious base, with a horizontal filter, and for the angle of inclination of the upstream face of the dam which equals 45°, the following conclusions may be made:

1- The height of the horizontal filter can be estimated as 0.16 of the total height of the dam. The spacing of the filter can be recommended to be 8.5 times the total height of the filter.

2- The values of the maximum length of the free water surface intersection (ℓ/F) with the horizontal filter appear at F/L = 0.04. The maximum value of its intersection (ℓ/F) equals 1.15 at H/T = 0.95.

REFERENCES

[1] Casagrande, A. Seepage through Dams, in *Contributions to Soil Mechanics* 1925-1940, Boston Society of Civil Engineering, Boston, 1940.

[2] Fathi Abdrabbo, "An Application of the Boundary Element Method To Seepage problem", II Unconfined Flow Problem, *The Bulletin of the Faculty of Engineering, Alex. Univ.*, vol. XXIV, 1985.

[3] Harr, M.E., *Ground Water and Seepage*, McGraw-Hill, New York, 1962.

[4] Hathoot, H.M., "Seepage through an Earth dam with a Horizontal Toe Filter", *the Bulletin of the faculty of Engineering, Alex. Univ.*, 1977.

[5] Kozeny, J: Ground wasserbewegung bei freiem Spiegel, Fluss und Konalversickerung, *Wasserkraft und Wasserwirts chaft*, no. 3, 1931.

[6] Numerov, S.N. (HyMepoB, C.H.), "On Seepage in Earth Dams with Drainage on Impervious Foundations", *Izv, NIIG*, vol. 25, 1939.

[7] Numerov, S.N., "Solution of Problem of Seepage without Surface of Seepage and without Evaporation or Infiltration of Water from Free Surface", *PMM*, vol. 6, 1942.

[8] Polubarinova-Kochina, P.Ya., "Theory of Ground Water Movement, translated by, Roger De Wiest, *Princeton University Press, Princeton, New Jersey*, 1962.