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SEEPAGE THROUGH AN EARTH DAM BASED ON AN IMPERVIOUS INCLINED BASE

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Abstract

Seepage through an earth dam based on an impervious inclined base is studied experimentally in this paper Using Hele-shaw model. In all experiments, the base width of the dam B, and the angle of inclination of its upstream face β , have had constant values equal 54.6 cm and 60°; respectively. For different values of the angle of inclination of the impervious bed α , the critical values of the upstream head H_c, at which the free surface intersects the toe of the dam are measured.

Seepage discharge is also measured and plotted versus the retained head (H) upstream the dam for different values of the angle of inclination (α).

The measured discharge values are compared with theoretical results given by MKhitarian [5].

Notation

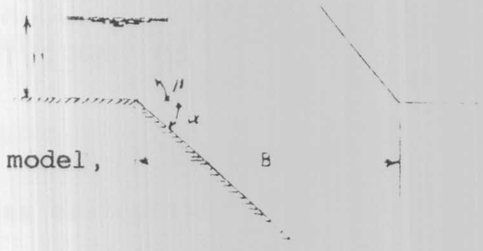


Figure (1) Geological section

a- half distance between the two prespex plates of the experimental model,

B- base width of the model = 54.6 cm,

g- acceleration due to gravity,

H- the retained head upstream the dam,

H_c- critical retained upstream head at which the free surface intersects the base of the dam.

K- hydraulic conductivity of the soil $=a^2.g/3\,\nu$,

q- seepage discharge per unit length Cm^3 /sec/cm,

α- angle of inclination of the impervious base of the dam

β- angle of inclination of the upstream face of the dam = 60^o and

ν- Kinematic viscosity of the oil at the experimental temperature cm^2/sec.

1. Introduction

Study of seepagc through an earth dam according to type of foundation can be classified into the following:

1- Seepage through an earth dam based on an impervious horizontal base,

2- Seepage through an earth dam based on an inclined impervious base,

3- Seepage through an earth dam founded on layer of finite depth with or without cut-off wall, and

4- Seepage through an earth dam founded on layer of infinite depth with or without cut-off wall.

The quantity of seepage through an earth dam depends upon, the retained head upstream the dam, the upstream surface of seepage, the angle of inclination of the impervious base and the hydraulic conductivity of the soil . The stability of the downstream part of the earth dam is influenced with different parametres such as the downstream slope of the dam, width of the road and the intersection of the free water surface with the extension of the downstream base level. This intersection gives the point where the minimum base width can be limited.

Elganiny [3], Hathoot [6,7] and Numerov [9] studied the problem of seepge through an earth dam without taking into consideration effect of inclination of the impervious base. Polubarinova- Kochina [8] developed on approximate procedure for the seepage characteristics of structures founded on two layerd systems underlain by an impervious base.

The problem of seepage through an earth dam on an inclined impervious base was treated mathematically by MKhitarian [5], the quantity of seepage is given by the following form :

$$q = \frac{KH \cot \pi \beta}{1+(\cot\pi(\alpha+\beta)/(J \sin\alpha\pi))(J_1+J_2)} \qquad (1)$$

where:

J is defined as: $$J = 2^{\alpha-1} \frac{\Gamma(\frac{1}{2})\Gamma(\frac{1}{2}-\alpha)}{\Gamma(3/2-\beta-\alpha)} \qquad (2)$$

The gamma function $\Gamma(x)$ is obtained from Ref.(1) , and

J_1 and J_2 are given by the series:

$$J_1 = \frac{1}{\frac{1}{2}-\beta}\left[\frac{\pi}{2} + 2^{\frac{1}{2}-\beta}\left(\frac{0.5^{1-\beta}}{1-\beta} + \frac{1 0.5^{2-\beta}}{2 2-\beta} + \frac{1 0.5^{3-\beta}}{3 3-\beta} + \ldots\right)\right] \qquad (3)$$

$$J_2 = -\frac{1}{\alpha+\beta-\frac{1}{2}}\left[\frac{\pi}{2} + 2^{\alpha+\beta-\frac{1}{2}}\left(\frac{0.5^{\alpha+\beta+1}}{\alpha+\beta+1} + \frac{1}{2}\,\frac{0.5^{\alpha+\beta+2}}{\alpha+\beta+2} + \ldots\right)\right] \qquad (4)$$

It is evident from Eq.(4) that for $\alpha+\beta=\frac{1}{2}$, the value of J_2 should be equal to ∞ and q equals o.o in Eq.(1) which indicates that results given for this case are not logic. Also the experimental results described in this paper showed big difference in comparison with MKhitarian's results.

The authors in the present study performed a number of experiments on a Hele-shaw model for different values of; =2.5,5,7.5,10,15,20,30, 40 and 50°. The angle of inclination of the upstream face of the dam(β)is taken constant and equals 60°, the retained upstream head ranges from 3.5 cm to 25.5 cm and the base width of the dam(B)is taken 54.6cm according to the designed dimensions of the model.

The aim of the present study is to give the designed base width (B/H_c) which represent the minimum base width of the dam for given values of the maximum retained head $(H)_{max}$, angle of inclination of the impervious base (α), and constant value of the angle of inclination of the upstream face $\beta = 60^{\circ}$.

A design chart, based on the experimental results, is plotted between the head retained upstream the dam and seepage discharge.

EXPERIMENTAL MODEL

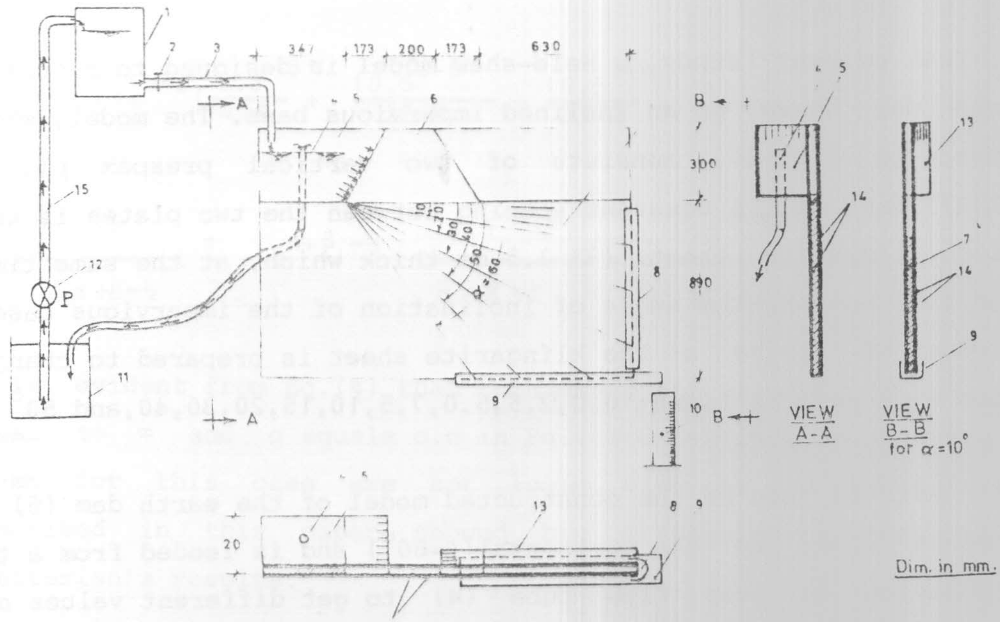
In the present study, a Hele-shaw model is designed to represent an earth dam based on an inclined impervious base. The model, which is shown in Fig.(2), consists of two vertical prespex plates(14) 1523x1190x10 mm , A constant spacing between the two plates is kept by using klingarite sheet (7) 1.5 mm thick which, at the same time, is used for changing the angle of inclination of the impervious base (α). A number of strips of the klingarite sheet is prepared to change the angle (α) several times; 0.0,2.5.5.0,7.5,10,15,20,30,40,and 50^{o} .

The upstream face of the constructed model of the earth dam (6) has a constant slope to the horizontal($\beta=60^{o}$) and is feeded from a tank (5) having an over flow tube (4) to get different values of the effective upstream head (H). The main supply tank (1) is connected to the feeder tank (5) by a tube (3) and the flowing oil (super 7500-20w/5o) is controlled by a valve (2).

A system of vertical and horizontal channels (8),(9)&(13) is put to collect oil in a graduated tube (10), hence the discharge can be measured.

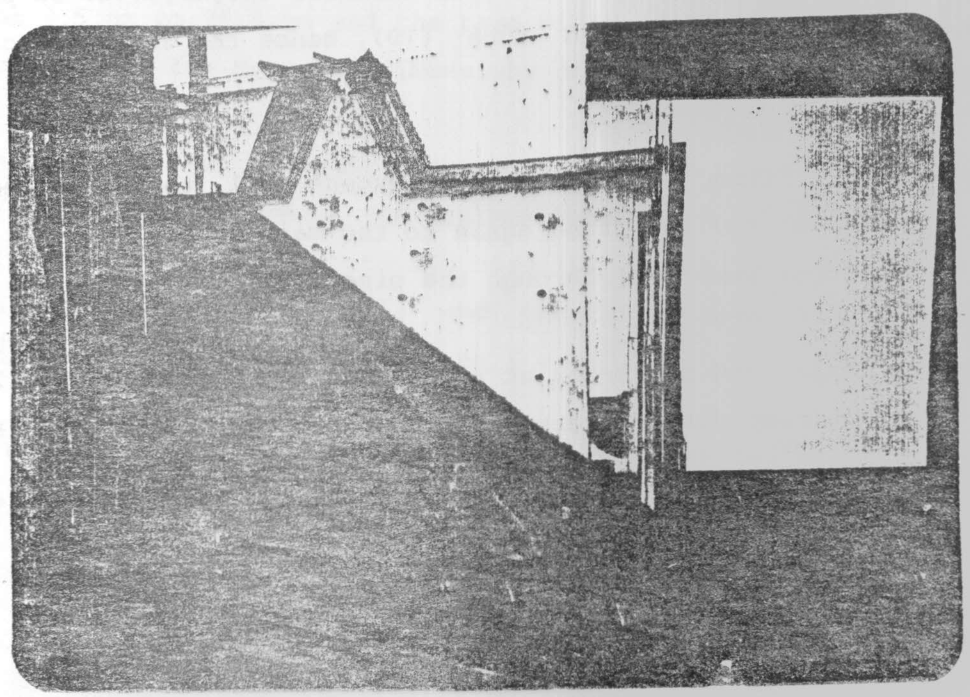
The over flow tube (4) discharges excess oil to the collecting tank(11)and the oil is lifted again to the main supply tank (1) by a small centrifugal pump (12) through the pipe (15).

The experiments are performed at a constant temperature equals 24^{o} where the corresponding hydraulic conductivity of the soil (K) is calculated.



1 - The main supply tank
2 - Control valve
3 - The feeder tube
4 - Over flow tube
5 - The feeder tank
6 - Model of the earth dam
7 - Impervious layers with different angles from 0.0 to 60 degrees
8 - Vertical channel
9 - Horizontal channel
10 - Graduated tube
11 - Collecting tank
12 - Centrifugal pump
13 - Side channel for collecting oil from the D.S. side of the dam
14 - Two prespex plates
15 - Delivery pipe

Figure (2) Experimental model.



2. Analysis of Results

A number of expleriments is carried out to fix the critical conditions at which filter must be constructed. For a constant angle of inclination (α), the head (H) is changed, the corresponding discharge is measured and the critical value of the head (H_c)is recorded corresponding to the fixed base width (B).

The values of($\frac{\alpha}{\beta}$) against (B/H_c) are plotted in Fig. (3) and recorded in table (1), it is evident that for a horizontal base width where " α " equals 0.0 and for a very small value of H_c, the value (B/H_c)is very large which means that a large base width is required, therefore filter is necessary in this case. For ($\frac{\alpha}{\beta}$)ranges from 0.042 to 0.833, Fig.(3) shows the critical case at which filter must be constructed for the constant value of B equals 54.6 cm. Generally, using Fig.(3), the minimum base width of the dam can be obtained for both the retained upstream head (H) and the angle of inclination of the impervious base (α). Figures (4,5) show the minimum base width at which filter must be constructed for α = 15 and 40 degrees and B/H_c= 4.37,2.41 respectivelly.The relation between the retained head (H/ B) and the corresponding values of the seepage discharge (q/KB) is shown in Fig.(6) and recorded in table (2). The seepage discharge increases with increasing both the retained head (H) upstream the dam and the angle of inclination of the impervious base of the dam.

A comparison is made based on quantity of the seepage discharge calculated mathematically by MKhitarian [5] and that measured experimentally by the authors. The mathematical reults given by [5], for a constant head H=10 cm, show that discharge increases with increasing angle of inclination " α " to limited value; " α " =

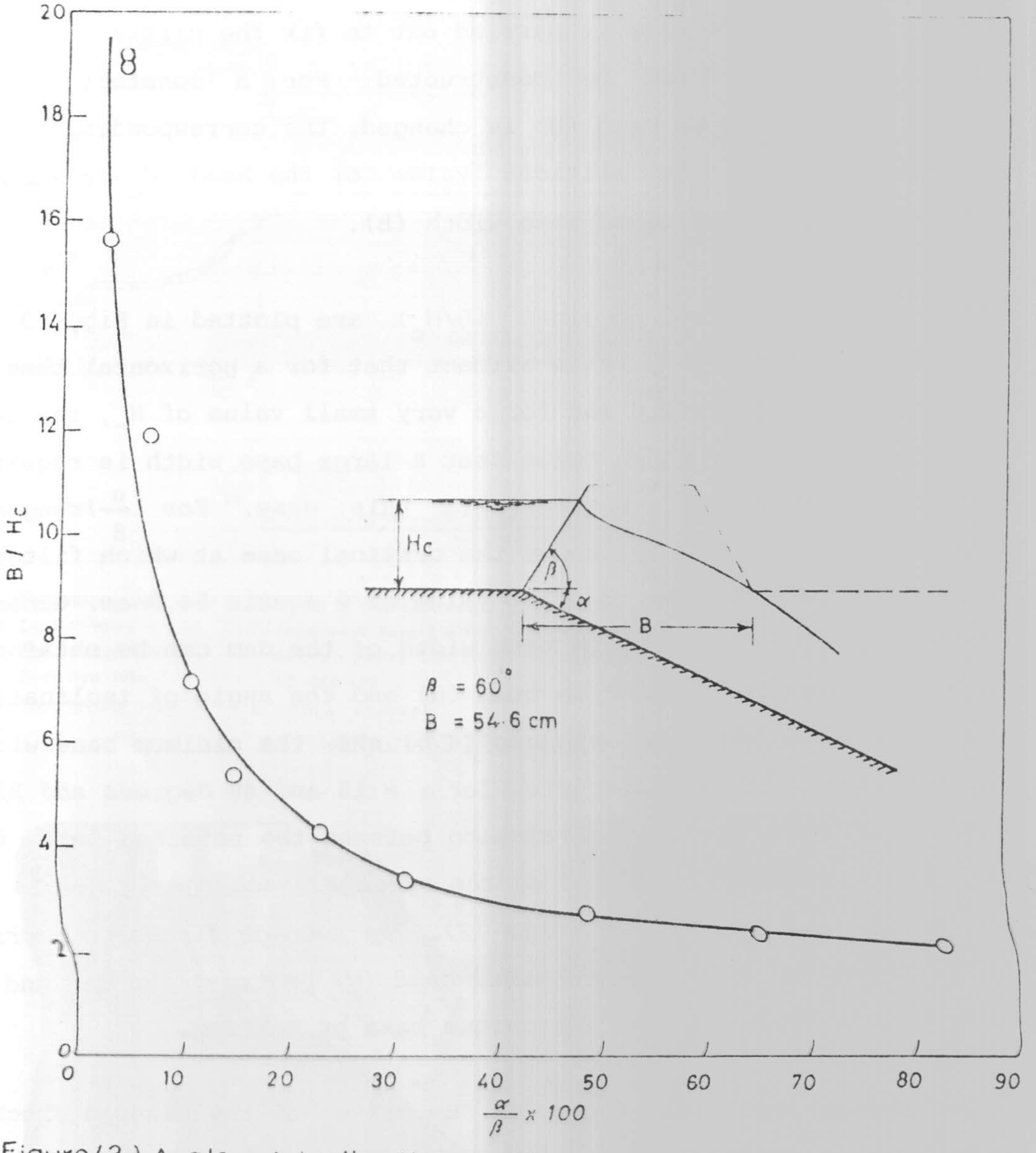


Figure (3) Angle of inclination of impervious base (α/β) versus the designed base width (B/H_c).

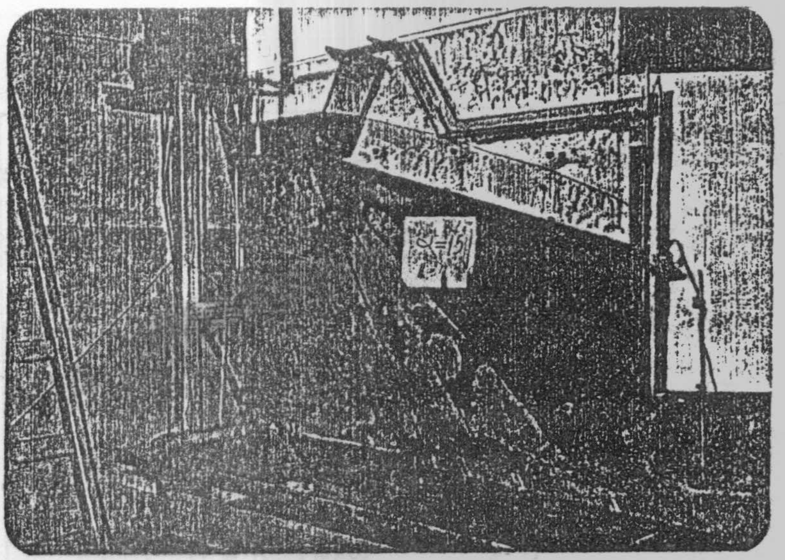


Figure 4 - Critical case for $\alpha = 15^{\circ}$

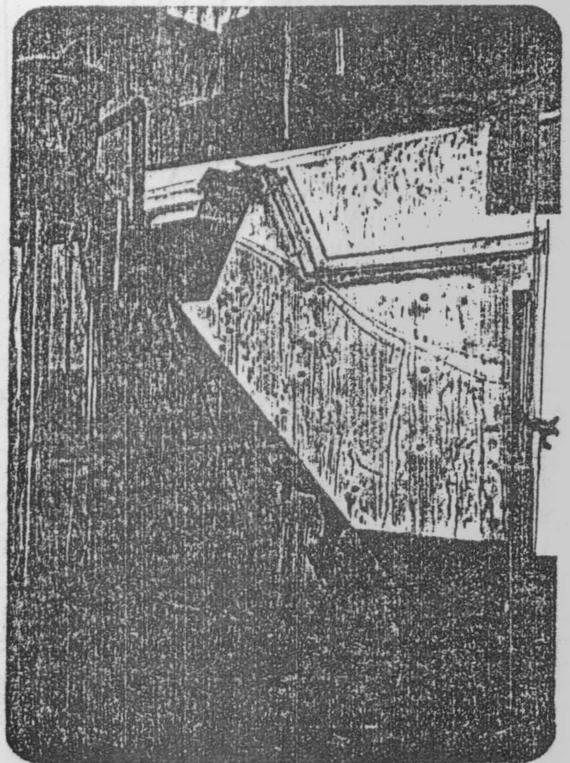


Figure 5 - Critical case for $\alpha = 40^{\circ}$

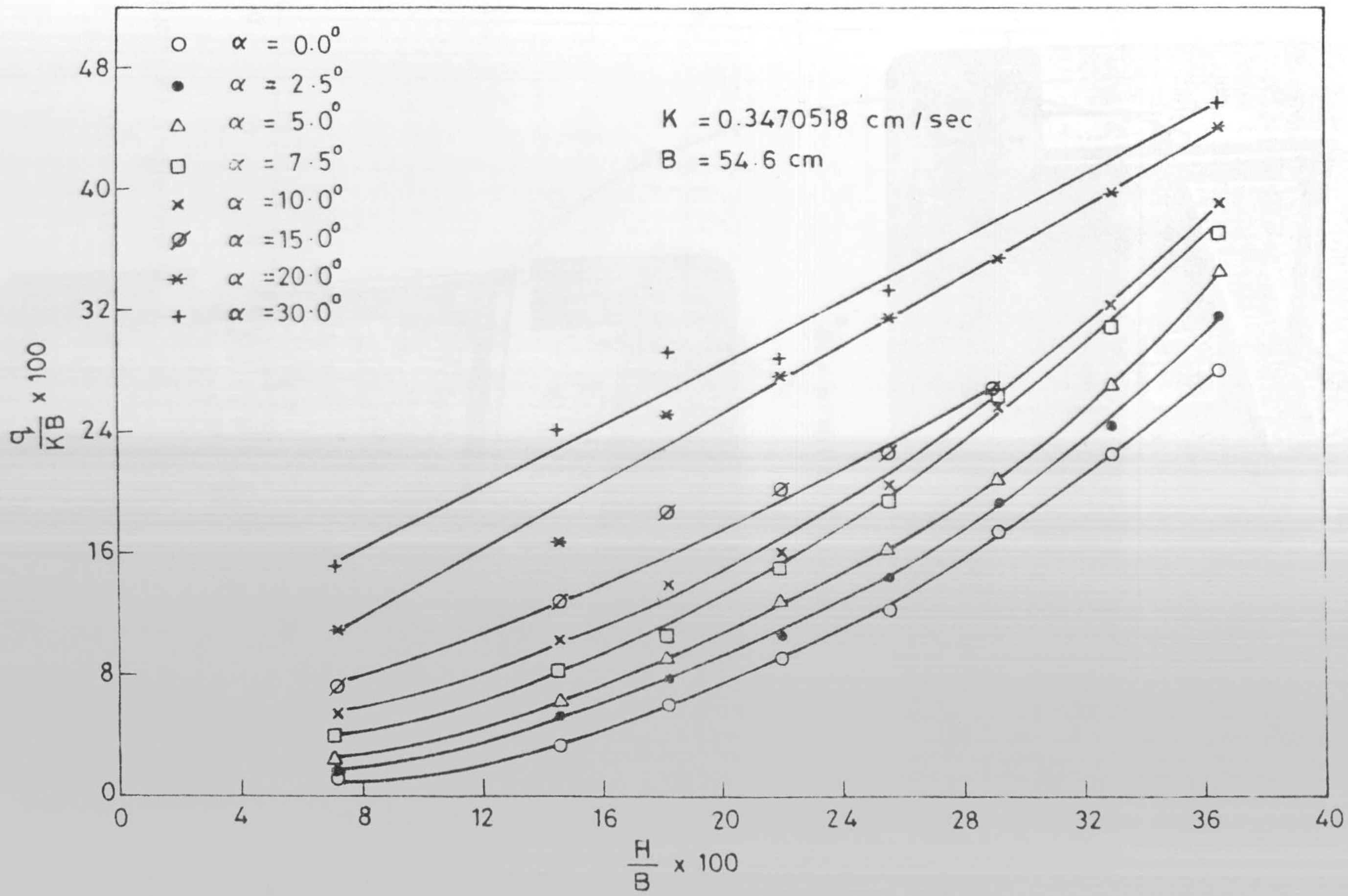


Figure.(6) Retained head upstream the dam (H/B) versus seepage discharge (q/KB).

Table (1) Values of B/Hc for B = 54.6 cm, $\beta = 60^{\circ}$, and different values of α

α°	2.5	5.0	7.5	10	15	20	30	40	50
H_c in cm	3.5	4.6	7.6	10.1	12.5	16.0	19.50	22.7	25.5
B/H_c	15.6	11.87	7.18	5.41	4.37	3.41	2.8	2.41	2.14
$\frac{\alpha}{\beta}$	0.042	0.083	0.125	0.167	0.25	0.333	0.50	0.666	0.833

Table (2) discharge values versus retained head upstream

H/B*100	7.33	14.65	18.32	21.98	25.64	29.30	32.97	36.63
ρ°	(q/KB) * 100							
0.0	1.12	3.322	5.993	9.357	12.244	17.768	22.55	28.296
2.5	1.358	5.863	8.088	10.726	14.803	19.69	24.66	31.981
5.0	2.24	5.583	9.323	12.998	16.287	21.279	27.486	34.902
7.5	4.272	8.665	10.348	15.476	19.914	26.785	31.273	37.268
10	5.35	10.565	14.129	15.992	20.454	26.12	32.575	38.87
15	7.525	13.176	18.983	20.376	22.552	25.997	29.942	35.89
20	11.133	17.008	25.743	28.07	31.696	35.718	40.208	44.647
30	15.363	24.319	29.482	28.837	33.35	—	36.34	45.81
40	17.078	20.297	28.48	36.648	48.062	58.636	64.357	74.067

20^{o} after which discharge decreases with increasing " α " afd tends to be zero for " α " = 30^{o}. This indicates that the mathematical results are not logic.

For the same constant head H=10 cm experimental results give an increase in seepage discharge with increasing the angle of inclination " α " . The average increase obtained experimeutally is about 13 times than that calculated mathematically. The big difference between mathematical and experimental results is shown in Fig.(7) and recorded in table (3).

3. Conclusions

An experimental study for seepage through an earth dam based on an impervious inclined base is carried out and the following conclusions are made:

Filter is necessary in case of horizontal impervious base. If (H) has a very small value and B is constant (Fig.3) then the value B/H should be equal agreat value, which means that alarge base width is reguired, therefore downstream filter must be constructed.

The minimum base width B/H_c of the earth dam can be designed for $\beta = 60^{o}$, and different values of $\frac{\alpha}{\beta}$ ranging from 0.042 to 0.833 (Fig.3).

A design chart is plotted (Fig.6) for the quantity of seepage discharge which increases with increasing both the retained head upstream and angle of inclination of the impervious base of the earth dam.

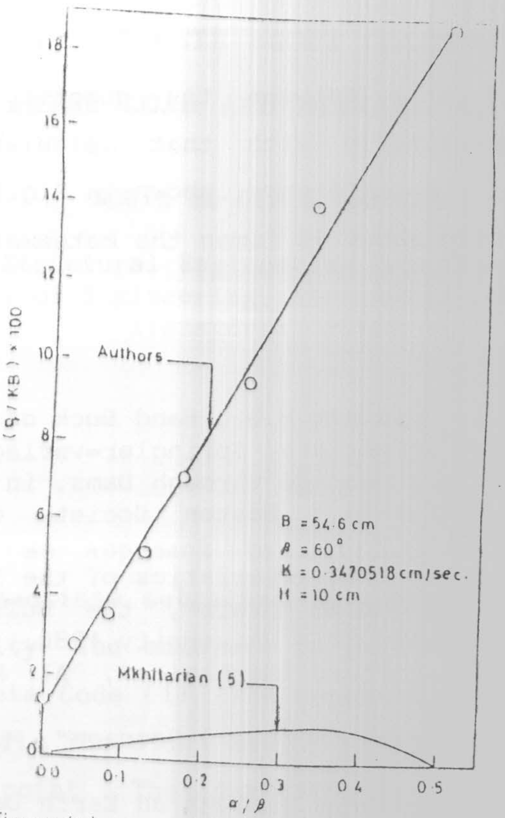


Figure (7) Angle of inclination of the impervious base (α/β) versus discharge (q/KB) .

Table(3) Discharges given by MKhitarian [5] and the authors versus (α)

α		0.0	1	2.5	5	7.5	10	15	20	25	30
$\frac{\alpha}{\beta}$		0.0	0.017	0.042	0.083	0.125	0.167	0.25	0.333	0.417	0.5
Discharge $(q/KB) \times 100$	Q_{th} by [5]		0.058	-	0.302	-	0.571	0.824	0.934	0.776	0.00
	Q_{exp} by the authors	1.4	--	2.8	3.6	5.2	7.2	9.6	14	--	18.8

$\beta = 60^{\circ}$, $B = 54.6$ cm, $K = 0.3470518$ cm/sec.

A comparison is made between the quantity of seepage discharge measured experimentally with that calculated mathematically by MKhitarian. The big difference, shown in Fig.(7), indicates that the experimental results about 13 times the mathematical results.

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