AN EXPERIMENTAL STUDY FOR SEEPAGE THROUGH AN EARTH DAM WITH CUTOFF WALL BASED ON AN INCLINED IMPERVIOUS BASE

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ABSTRACT

Study of seepage through an earth dam with cutoff wall based on an inclined impervious base is carried out experimentally. The study aims to investigate the effect of both penetration depth of cutoff wall and its distance measured from the heel of the dam on both seepage discharge and loss of head due to cutoff wall. Free water surface is recorded experimentally according to variation of the retained head upstream the dam in each case of penetration depth of the cutoff wall and its distance.

NOTATIONS

- a half distance between the two prespex plates of the experimental model,
- d penetration depth of the cutoff wall measured from the upstream base level of the dam,
- g acceleration due to gravity,
- H the retained head upstream the dam,
- Δh loss of head due to cutoff wall,
- K hydraulic conductivity of the soil = $a^2.g/3\upsilon$ = cm/sec,
- q seepage discharge per unit length $cm^3/sec/cm$,
- x distance of cutoff wall measured from the heel of the dam,
- α angle of inclination of the impervious base of the dam,
- (x tanα-d) -path length of seepage discharge,
- β angle of inclination of the upstream face of the dam, and
- υ kinematic viscosity of the oil at the experimental temperature cm^2/sec.

INTRODUCTION

Cutoff walls are generally used to lower the free water surface and hence reduce the required width of the earth dam. The solution of seepage through earth dam founded on layer of finite depth with cutoff wall was first given by polubarinova-kotchina [2], based on the solution given earlier by Voshchinin [7] for the length of cutoff wall equals zero. The same problem was also studied by Mkhitarian [3] and Skornyakov [5].

Shornyakov [5] gave an approximate solution for the seepage characteristics through a hamogeneous earth dam with an impervious core founded on a base of great depth. Also Shornyakov [5] solve mathematically the problem of earth structure with cutoff wall at toe. Seepage through an earth dam based on an impervious inclined base was studied experimentally by Mohamed Rezk and Rabiea Nasr [4]. The problem studied experimentally in this paper is seepage through an earth dam with cutoff wall based on an inclined impervious base, as represented by the geological section in Figure (1).

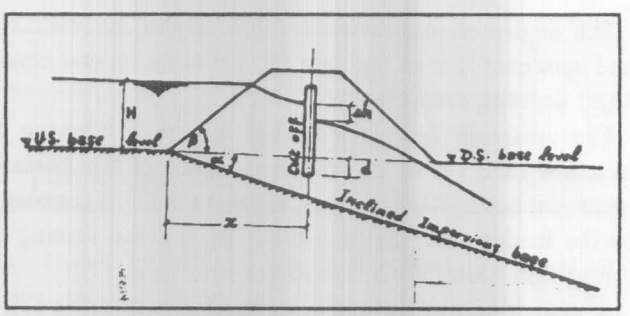

Figure 1. Geological section.

Number of experiments are carried out to investigate the effect of the penetration depth (d), which is measured from the upstream horizontal base level of the dam, its distance (x) on both seepage discharge (q) and loss of head due to cutoff wall (Δh). The upstream and the downstream base of the dam at the same level. The distance (x) of the cutoff wall is measured from the heel of the dam. Cutoff wall is considered impermeable.

EXPERIMENTAL MODEL

The problem of seepage through an earth dam with cutoff wall based on an inclined impervious base is experimentally studied using a Hele-Shaw model. The model, which is shown in Figure (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. A vertical strip represents cutoff is made from the same klingarite sheet having a constant wide 2 cm.

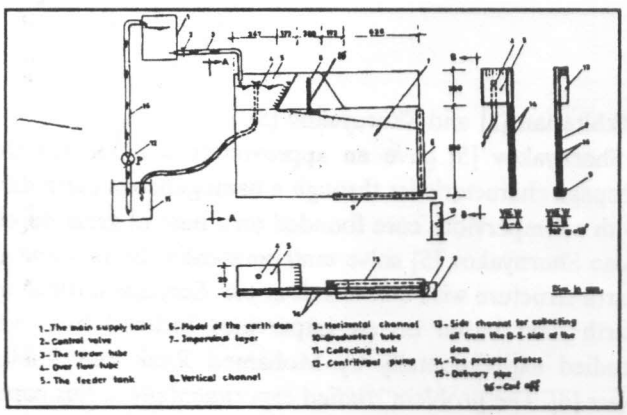

Figure 2. Experimental model.

The angles of inclination of both impervious base (α) and upstream face of the dam (β) are constant and equals 10,60 degrees, respectively.

The upstream face is fed from a tank (5) having an overflow 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/50) 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 discharge can be measured and at the same time loss of head (Δh) is recorded.

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 27° where the hydraulic conductivity of the soil (K) is calculated.

ANALYSIS OF RESULTS

An experimental study is carried out, on a Hele-shaw model representing an earth dam with cutoff wall based on an inclined impervious base, to investigate effect of penetration depth of the cutoff wall (d) and its distance (x), as shown in Figure (1), on both seepage discharge (q) and loss of head due to cutoff wall (Δh).

For constant value of angle of inclination of the impervious base (α = 10), distance of cutoff wall (x) and penetration depth (d), the retained head (H) is changed five times; H=4,6,8,10 and 12 cm and the corresponding seepage discharge (q) and loss of head (Δh) are measured. Distance (x) is changed four times; x=10,20,30 and 40 cm. For each value of (x), the penetration depth (d) is changed several times. Results are shown in Figs. (3), (4) & (5) and also recorded in tables (2) & (3).

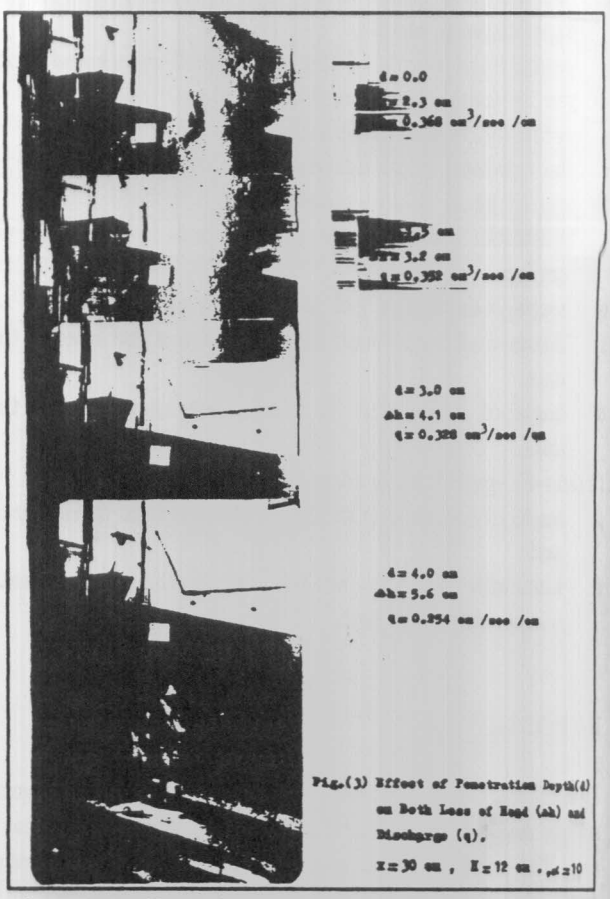

Figure 3. Effect of penetration depth (d) on both loss of head (Δh) and discharge (q). x = 30 cm, H = 12cm., α = 10.

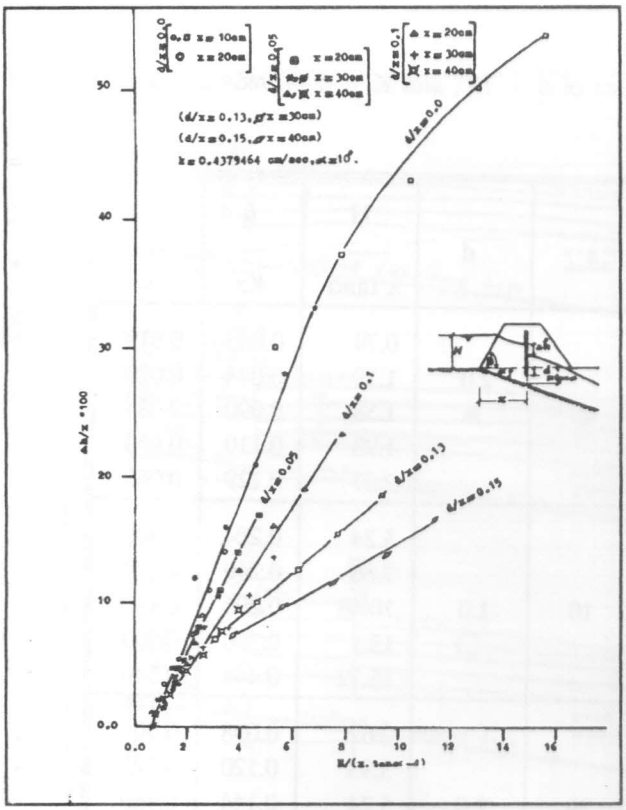

Figure 4. Loss of head ($\Delta h/x$) Versus $H/(x.\tan \alpha - d)$.

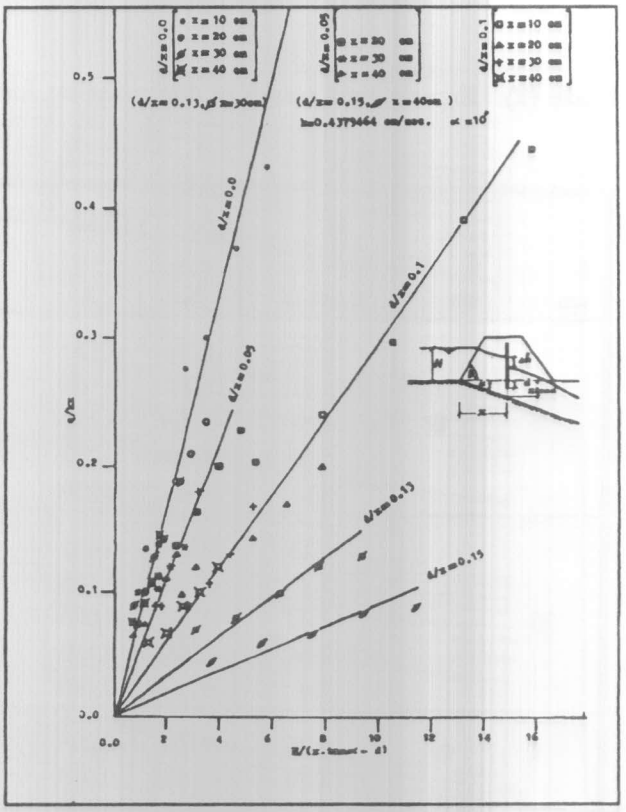

Figure 5. Discharge ratio q/kx versus $H/(x.\tan \alpha - d)$.

Table 1. Effect of penetration depth (d) on both loss of head (Δh) and seepage discharge (q).

d cm	0.0	1.5	3.0	4.0
Δh cm	2.3	3.2	4.1	5.6
q $cm^3/sec/cm$	0.368	0.352	0.328	0.254

The effect of penetration depth (d) on loss of head (Δh) is shown in Figure (3), for the constant value of H = 12 cm, α = 10 and x=30 cm and for different values of d=0.0, 1.5, 3.0 & 4.0 cm. For these values of (d) the corresponding values of (Δh) and (q) are as follows: The results indicate that the increase of penetration depth (d) increases loss of head (Δh) and decreases seepage discharge (q). This is because path length of discharge (x) tan α-d) decreases with increasing (d), therefore discharge decreases and loss of head increases.

The results given in table (3) indicate that for $\alpha = 10°$, the retained head upstream the dam (H) should not be less than 0.76 the path length of seepage discharge, at which the free water surface touches the lower end of the cutoff, i.e $\Delta h = 0.0$. For the cutoff to be effective H should be bigger than 0.76(x tan α-d) which gives $\Delta h > 0.0$.

Design charts are plotted between $\Delta h/x$ versus $H/(x \tan \alpha - d)$ and q/Kx versus $H/(x \tan \alpha - d)$ in Figures (4) and (5) respectively for different values of d/x=0.0, 0.05, 0.1, 0.13 and 0.15.

The free water surface is drawn experimentally and is shown in Figure (6) for different values of penetration depth (d) and its distance (x).

Table (2). Experimental results in dimensionless form for values of α = 10°, and K = 0.4379464 cm/sec.

x cm	d cm	H / x tan α	q / Kx	Δh / x	H cm	x	d	H / x tanα	q / Kx	Δh / x
		2.27	0.276	0.120	4			0.79	0.065	0.013
10	0.0	3.41	0.300	0.160	6		2.0	1.19	0.074	0.023
	●	4.55	0.368	0.210	8	40	▲	1.58	0.090	0.035
		5.68	0.430	0.280	10			1.98	0.110	0.053
		6.82	0.564	0.330	12			2.37	0.129	0.068
		1.13	0.134	0.035	4			5.24	0.204	0.300
	0.0	1.7	0.138	0.055	6			7.86	0.240	0.370
20	o	2.27	0.188	0.075	8	10	1.0	10.48	0.296	0.430
		2.84	0.210	0.110	10		□	13.1	0.390	0.500
		3.4	0.234	0.140	12			15.72	0.444	0.540
	ϕ	0.76	0.091	0.00	4			2.62	0.098	0.90
		1.13	0.102	0.016	6			3.93	0.120	0.125
		1.51	0.128	0.037	8	20	2.0	5.24	0.144	0.160
30	0.0	1.89	0.143	0.053	10		△	6.55	0.170	0.190
		2.26	0.188	0.077	12			7.86	0.198	0.235
		0.57	0.076		4			1.75	0.087	0.043
		0.85	0.074	0.010	6			2.62	0.088	0.063
		1.13	0.092	0.023	8	30	3.0	3.49	0.109	0.080
40	0.0	1.42	0.108	0.033	10		+	4.37	0.130	0.107
	⊠	1.7	0.147	0.048	12			5.24	0.168	0.137
		1.58	0.112	0.045	4			1.31	0.059	0.028
		2.37	0.138	0.080	6			1.97	0.068	0.035
		3.17	0.164	0.110	8	40	4.0	2.62	0.090	0.058
20	1.0	3.96	0.200	0.140	10	12	¤	3.28	0.098	0.078
	◪	4.75	0.228	0.170	12			3.93	0.120	0.095
		1.06	0.097	0.023	4			3.1	0.070	0.070
		1.58	0.104	0.040	6			4.65	0.080	0.100
		2.11	0.120	0.056	8	30	4.0	6.2	0.099	0.127
30	1.5	2.64	0.137	0.080	10		⊄	7.75	0.120	0.157
	★	3.17	0.180	0.106	12			9.3	0.128	0.187
					4			3.8	0.046	0.075
					6			5.7	0.060	0.098
					8	40	6.0	7.6	0.066	0.118
					10		⌀	9.5	0.083	0.138
					12			11.4	0.087	0.165

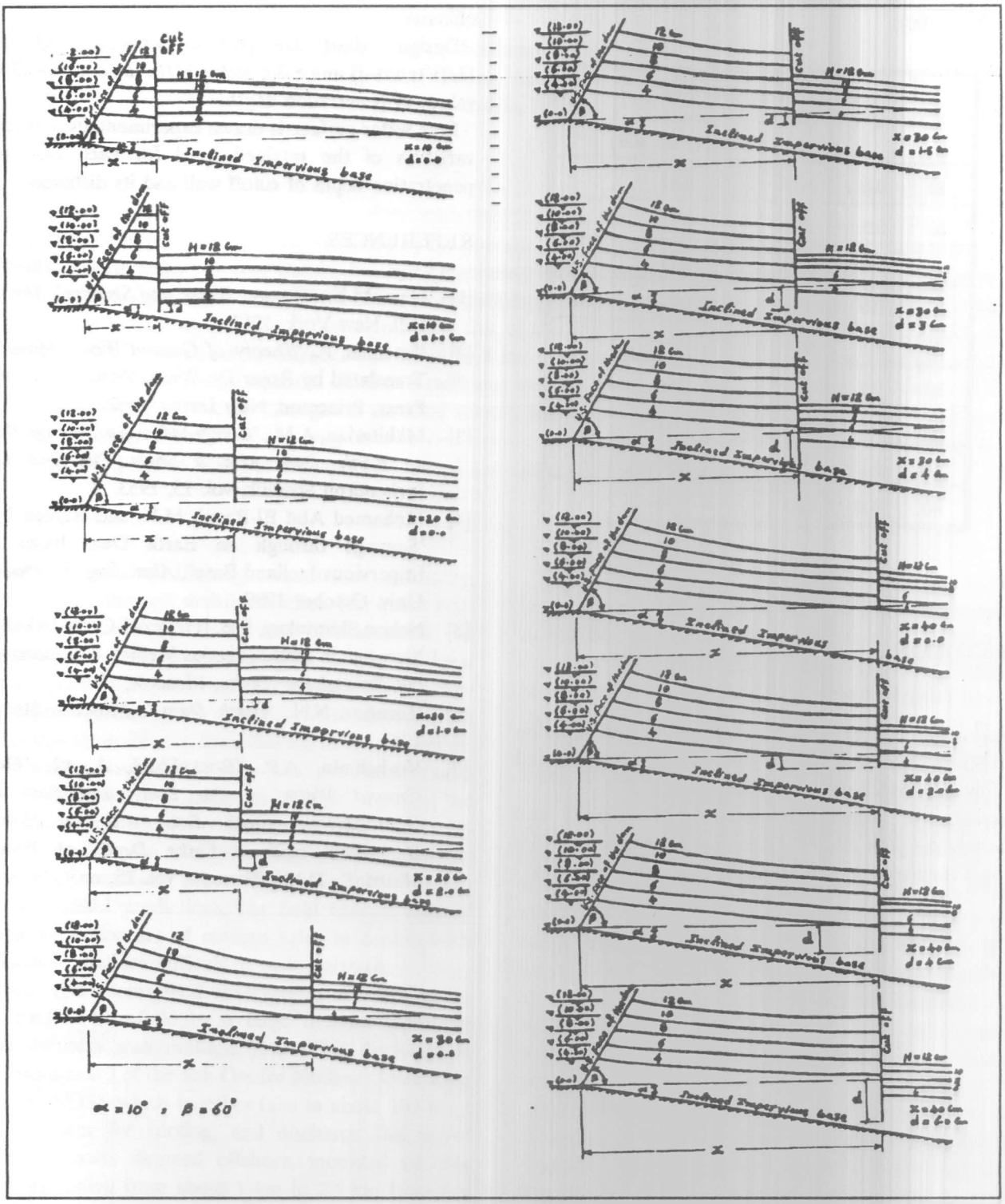

Figure 6. Free water surface ass recorded from experiments.

Table (3). Experimental results in case of free water surface just touch the lower end of the cut-off (i.e. $\Delta h = 0.00$).

x	d	H	$\frac{H}{(x \tan \alpha - d)}$
10	0.0	1.1	0.62
20	0.0	2.4	0.68
20	1.0	1.8	0.71
30	0.0	4	0.76
30	1.5	2.7	0.71
30	3.0	1.7	0.74
40	0.0	5.3	0.75
40	2.0	3.7	0.73
40	4.0	2.3	0.75

CONCLUSIONS

Seepage through an earth dam with cutoff wall based on an inclined impervious base is studied experimentally and the following conclusions are obtained:

Increase the penetration depth of the cutoff wall decreases the path length of seepage discharge therefore seepage discharge decreases and loss of head increases.

The retained head upstream the dam should be bigger than 0.76 (x tan α-d) for $\alpha = 10^{\circ}$ so that cutoff may be effective.

Design chart are plotted between $\Delta h/x$ versus $H/(x \tan \alpha - d)$ and q/kx versus $H/(x \tan \alpha - d)$ for different values of penetration depth.

Free water surface is drawn experimentally according to variation of the retained head for each case of the penetration depth of cutoff wall and its distance.

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