OPTIMAL NUMBERS AND POSITIONS OF THE RELIEF VALVES IN LINED CANALS

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ABSTRACT

Canal lining is usually constructed in soil of high permeability, so that loss of water from canals is to be as minimum as possible. In lands subjected to high ground water table, the lining suffers from a great value of uplift pressures which leads to a thick canal lining and a big cost. To save this big cost of lining,the use pressure relief valves are recommended . In this paper the optimal position of the relief valves in plain concrete lined canals is studied experimentally on a sand model, and their locations are recommended to get a minimum thickness of the canal lining. Also the optimal number of the relief valves along canal cross section is investigated.

Keywords: Canal lining-relief valves-Uplift forces-Modeling.

NOTATION

b	position of the relief valve measured from canal center,
B	Canal bed width,
$[C_H]_p$	horizontal distance of the calculated pressure affecting on the prototype bed,
$[C_I]_p$	inclined distance of the calculated pressure affecting on the prototype slope,
d	valve diameter in model, equals 3 mm,
E_m	Euler's number in model,
γE_p	Euler's number in prototype,
h	head loss in general,
h_m	head loss at the point of measuring pressure on the model in cm,
h_p	head loss at the point of measuring pressure on the prototype in m,
H	total head of water in general,
H_m	total head of water affecting on model in cm,
H_p	total head of water affecting on the canal lining in m,
K_m	permeability coefficient in experiment, cm/sec,
K_p	permeability coefficient in prototype,m/s,
ℓ	half width of the canal cross section , denoted by Eq. (8),
L	length of the canal side slope (L=H/sinα),
L_m	model length,
L_p	prototype length.
L_r	model ratio (L_m/L_p),
P_m	vertical pressure in model, gm/cm^2
P_p	vertical pressure in prototype, t/m^2,
S	position of the relief valve measured from the lower point of the canal side slope, Figure (5),
V_m	velocity of water through the porous medium of the sand model,
V_p	velocity of water through the porous medium of the prototype,
T.U.F.	total uplift force (t/m'),
C.T.L.	critical thickness of lining (in cm),
γ_c	Specific weight of the plain concrete =2.2 t/m^3
γ_s	Specific weight of the sand, and
α	Inclination angle of the side slopes for the models and prototypes with horizontal,it is taken as a constant value equals, $\alpha = \tan^{-1} 0.5$.

INTRODUCTION

Canal lining has a main function such as coatings to prevent scour of both bed and sides, damage from floating bodies, and reducing quantity of water percolating from the canal [4]. Canals can be lined with hard surface linings such as unreinforced concrete, asphaltic material, pitching in morter or with flexible lining like asphalt, cement morter, and plastic sheets.

Canals also are lined with soil material like clay with less permeability . The various types of linings available were examined and described by Richard [10], The respective advantages, disadvantages, and limitations were enumerated. Graphs were prepared by Thomas [12] based on a direct algebraic technique to determine open channel cross sectional designs which minimize lining costs when base and side slope unit costs are different. Ronald [11] described the methods used in investigation, designing, and constructing the P.V.C lining, He also summarized the construction costs from 1973 to 1982 on the Riverton unit in central Wyoming. Seepage rate from a large, concrete-lined canals with unsealed contraction joints was evaluated through full-scale field tested by Kishel [6]. The observed seepage rate was compared with that reported for similar canals with sealed contraction joints. The comparison indicated that contraction joint seals have little significant mitigating effect on canal seepage rate. Abdrabbo et al [1] showed that stability of a heading-up structure is greatly affected by the formation of the upstream and/or downstream cracks in the canal lining. They used the boundary element method to analyze the uplift pressure on the floor and on the lining itself. El-Fitiany et al [3] studied the problem of seepage under the floor of a pumping station, resulting from limited upstream and downstream cracks in the canal lining using the boundary element method. Characteristics and observed stability of fine and coarse soils for covering layers which placed on 16 selected canal reaches to resist water erosion and to protect asphalt, plastic member one, and compacted earth linings were reported by Chester [2]. The purpose of his investigation was to establish guideline, particularly for grain-size distribution, for the selection of future covers based on past experience on canals in USBR (Bureau of Reclamation). A theoretical analysis of flap-valve performance was undertaken by Mevorach and Zanker [8] to provide the necessary guidance for the laboratory experiments that followed and to aid in the interpretation of the results of the experiments. The present work aims to safe costs of canal lining, for the case under study shown in Figure (1), by choosing both of the optimum numbers and positions of the relief valves along the canal cross section, which gives the minimum uplift force. The following assumptions are considered in the study:

1- The canal is to be constructed in a highly permeable soil overlying an impervious layer with high ground water table.The depth of the impervious layer below the canal bed equals (d).
2- For the worst case, canal is considered to be empty, so that maximum external load can be achieved.
3- The side slope of the canal is taken 2 horizontal to 1 vertical.
4- Permeability coefficients are equal in both model and prototype.
5- The assumed valve in the present study is nonreturn valve.

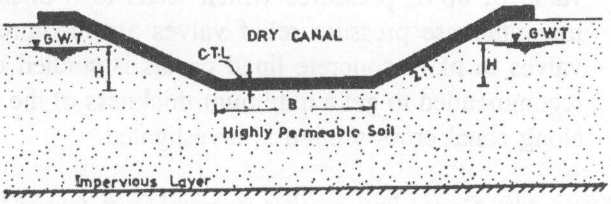


Figure 1. Geological section of the case under study.

<u>The sand Model</u>

The sand model Figure (2) is used in the experimental work to study the optimum position of the relief valves in lined canals. It consists of two prespex boxes. The internal box contains the canal model resting on a sandy soil of specific weight and permeability coefficient as shown in Table (A-3) . The grain size distribution of the used sand also given in Figure (A-1).For symmetry half of the canal section is to be considered in the internal box . The canal model includes piezometers distributed along the wetted perimeter of the canal model. Height of water in piezometers are read on a fixed vertical scale. The valves are represented by holes perpendicular to the surface of the prespex, and distributed along the wetted perimeter of the canal model. Vertical steel bars with a screw ends are used to close or to open the valves. A constant head of water can be achieved, in the outer box, using an overflow tube. Water moves through the perforated bottom of the internal box to satisfy the same constant head in the outer box. To keep sand in the inner box, a synthetic material is stuck on the perforated bottom. In case of opened valves, a side hole is used to get rid of excess water entering the model. Four models are used in the present study with the dimensions, B/H=8,4,2, and 1.2, Figure (3).

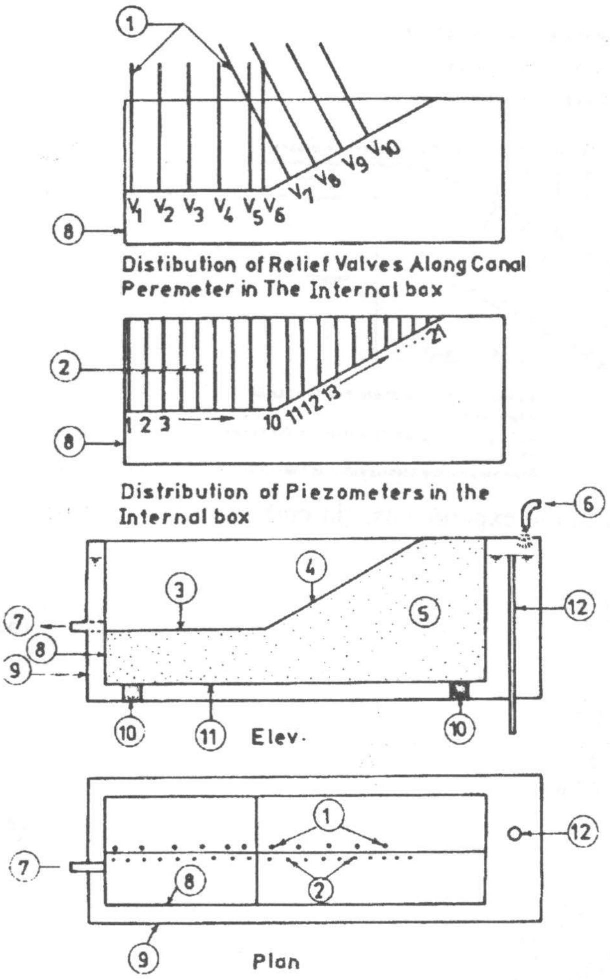


Figure (2). The Sand Model.

1-Steel Bars With a Screw Ends.
2-Piezometers.
3-Bed of the Canal Model.
4-Sid Slope of the Canal Model.
5-Sand.
6-Source of Water.
7-Side Hole.
8-Internal box.
9-Outer box.
10-Support.
11-Perforated Bottom of the Internal box
12-Over Flow Tube.

Procedure of experiments

1- For the used model of the half canal cross section, B/H = 4, the two values No (1,7), Figure (3), are opened and the heights of water in the piezometers are measured and recorded. (This means that four valves are opened along the canal cross section).

2- Step No "1" is repeated several times with opening the valves No (2,7), (3,7), (4,7),. (5,7) and (6,7).

3- The mentioned procedure in steps "1" and "2" is followed in the following groups of valves:
  a- (1,8), (2,8), (3,8), (4,8), (5,8) and (6,8),
  b- (1,9), (2,9), (3,9), (4,9), (5,9) and (6,9), and
  c- (1,10), (2,10), (3,10), (4,10), (5,10) and (6,10).

4- The value of B/H is changed into 8,2 and 1.2 and in each case, steps "1", "2" and "3" are repeated.

5- The recorded data is put in a table form as shown in Tables (A-I-a,b,c and d).

6- Some experiments are carried out using only two opened valves along the canal cross section instead of four.They are located at the same optimum distance resulted from using four valves. This is carried out to see effect of the relief valves, constructed on the side slope of the canal, on thickness of lining and to evaluate the optimum number of valves used along canal cross section. Table (A-2) shows results for using two valves only along canal cross section.

Modeling of pressures

To estimate the actual total uplift force affecting on the prototype and to find the critical thickness of lining, the measured pressure from experiments must be transformed into the prototype one using Euler's and Darcy's formulae. Euler's number is used to find the similarity between model and prototype in calculation of water pressures:

$$E = \frac{M.a}{p.A} = \frac{\rho.V^2}{p} \quad \text{Ref.[9]} \qquad (1)$$

Darcy's low is used to calculate velocity in porous media

$$V = K.i = k\frac{h}{L} \quad \text{Ref.[5]} \qquad (2)$$

$$\therefore E_m = E_p$$

$$\rho\frac{V_m^2}{p_m} = \rho\frac{V_p^2}{P_p}$$

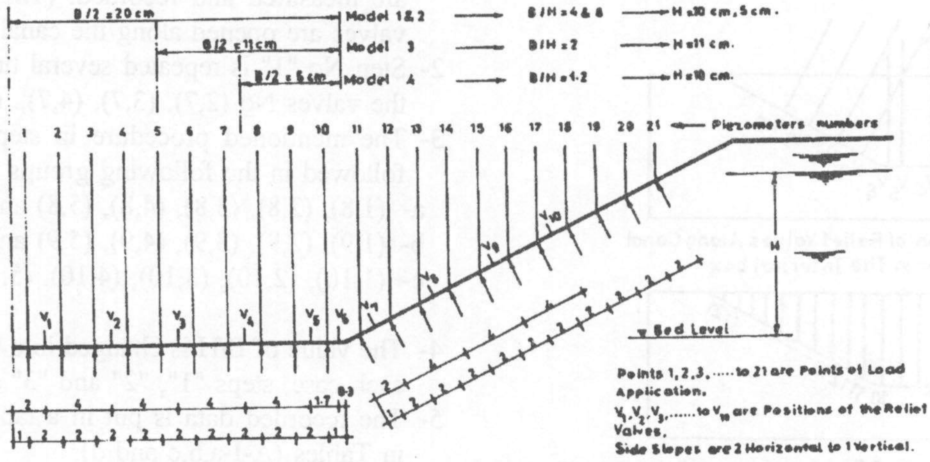
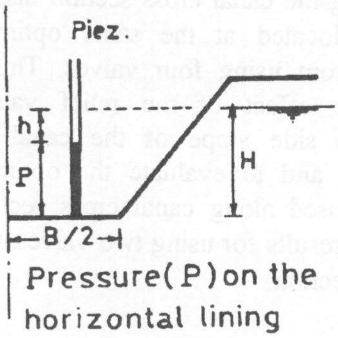


Figure 3. Dimensions of the models used in the experiments, (in cm).

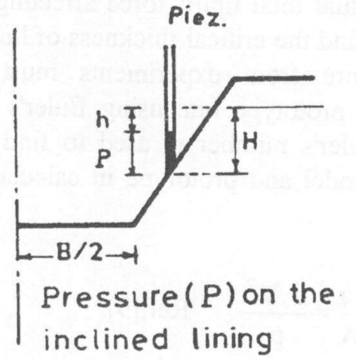


$$\rho\,\frac{k_m^2 (h_m/L_m)^2}{P_m} = \rho\,\frac{K_p^2 (h_p/L_p)^2}{P_p} \qquad (3)$$

$$(\frac{K_m}{K_p})^2 \frac{h_m^2}{L_m^2 P_m} = \frac{h_p^2}{L_p^2 P_p}$$

$$P_p = H_p - h_p \qquad (4)$$

$$\therefore (\frac{K_m}{K_p})^2 \frac{h_m^2}{L_m^2 P_m} = \frac{h_p^2}{L_p^2 (H_p - h_p)}$$



$$h_p^{\,2} = (H_p - h_p)\,(\frac{L_p}{L_m})^2 (\frac{K_m}{K_p})^2 . \frac{h_m^2}{P_m}$$

$$\therefore h_p^{\,2} + b'\,h_p - b'H_p = 0.0 \qquad (5)$$

where:

$$b' = (\frac{L_p}{L_m})^2 (\frac{K_m}{K_p})^2 . \frac{h_m^2}{P_m} \qquad (6)$$

$$\therefore h_p = \frac{1}{2}[-b' \pm \sqrt{b'^2 + 4.b' H_p}] \qquad (7)$$

From Eq. (7), head loss at the point of measuring pressure in prototype can be determined, and from Eq. (4), pressure can be calculated.

Four prototypes are prepared Figure (4), based on the experimental models, and put under study to satisfy the main purpose of the present work.

The opposite procedure can be also applied, if modeling required to be done for any prototype under study.

The following Table (1) shows the models and the corresponding prototype dimensions.

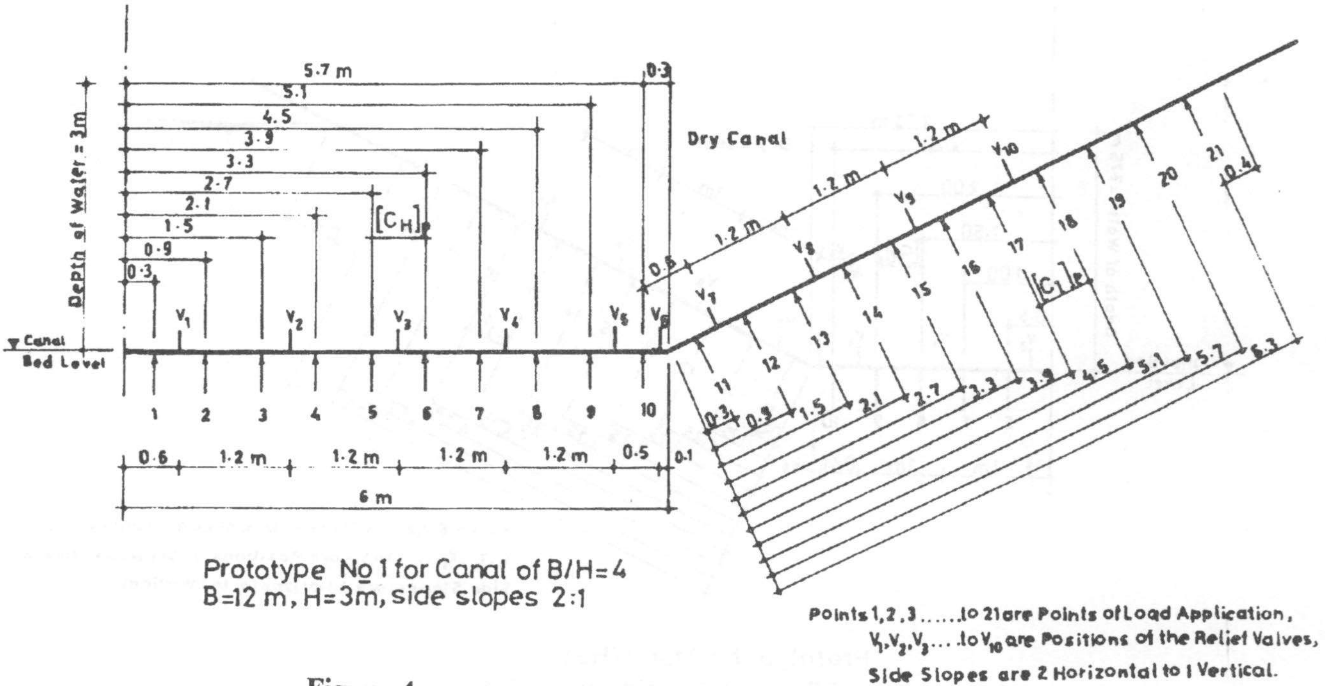


Figure 4-a.

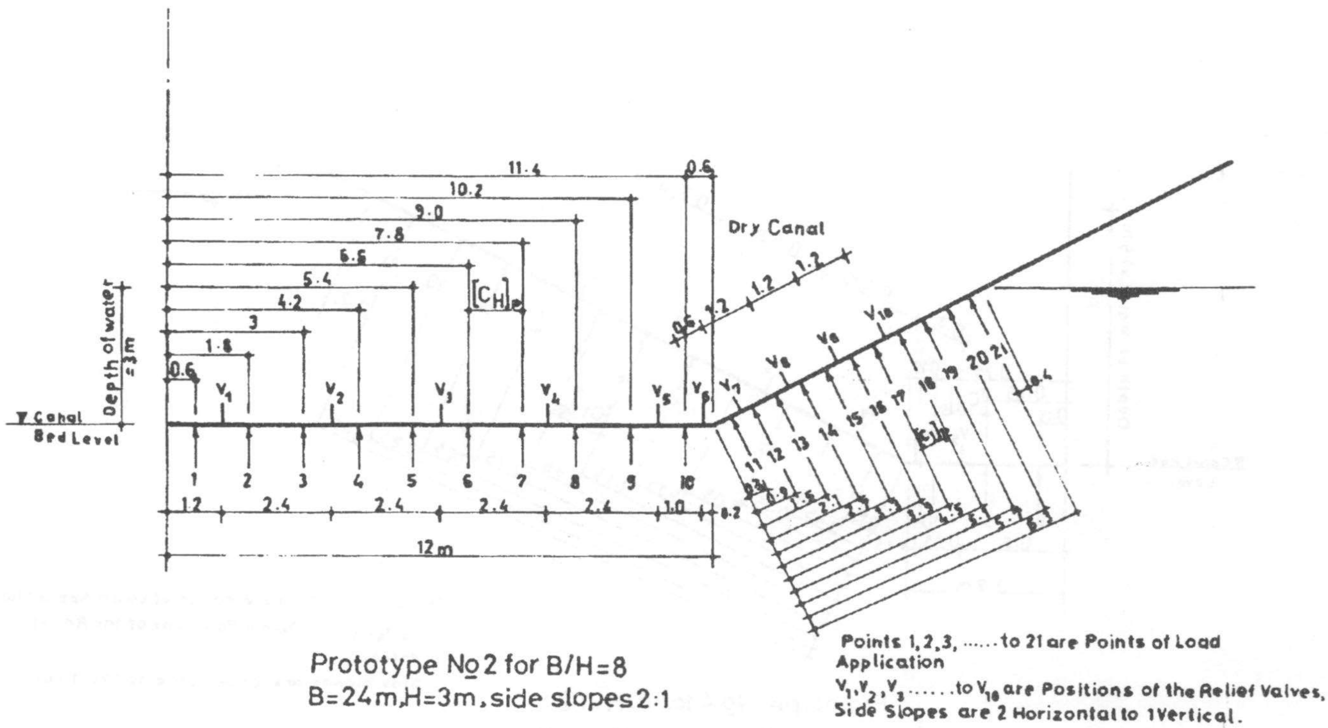
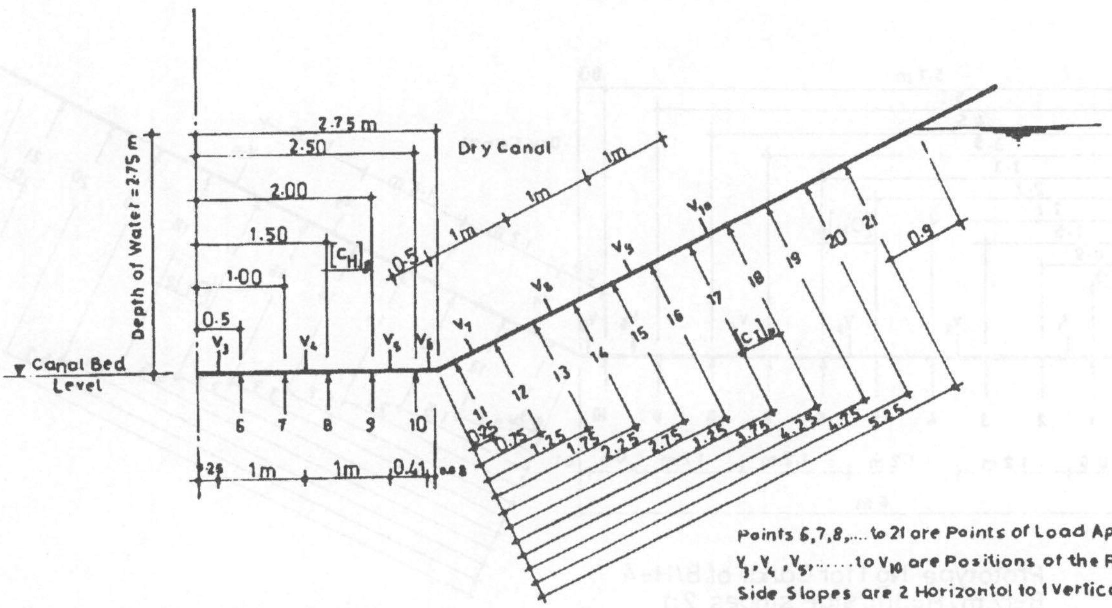
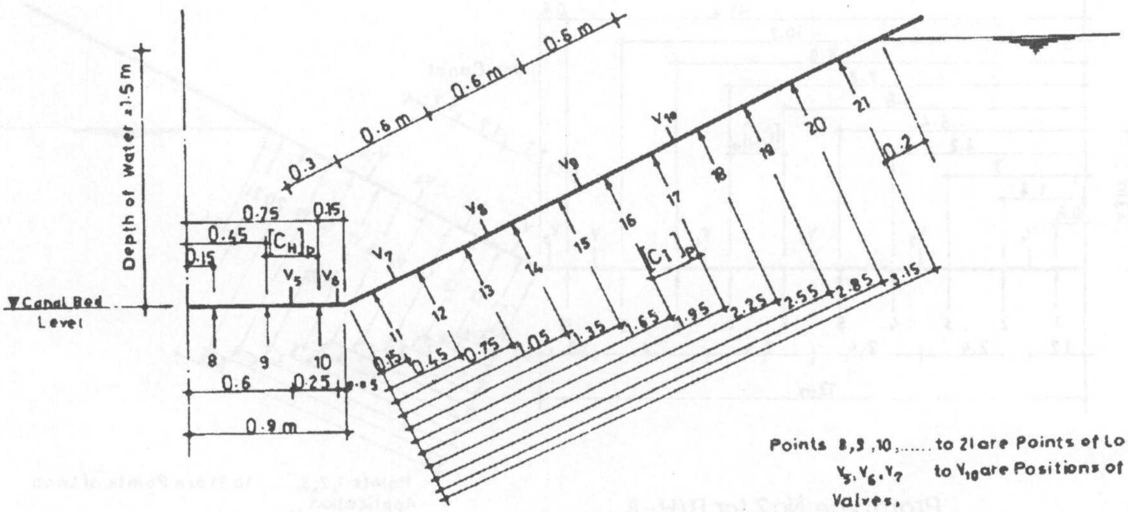


Figure 4-b.



Prototyp No 3 for B/H=2
B=5.5m, H=2.75m, side slopes 2:1

Figure 4-c.



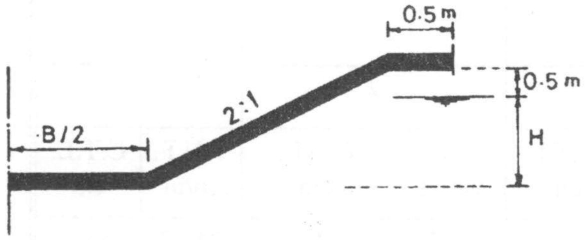
Prototype No 4 for B/H=1.2
B=1.8m, H=1.5m, side slopes 2:1

Figure 4-d.

Figure 4. Prototypes used in analysis.

Table 1. Dimensions of both models and the corresponding prototypes.

B/H	L_r	Models		Prototypes				
		B cm	H cm	B m	H m	$[C_H]$ m	$[C_I]$ m	ℓ m
8	60	40	5	24	3	1.2	0.6	20.33
4	30	40	10	12	3	0.6	0.6	14.33
2	25	22	11	5.5	2.75	0.5	0.5	10.52
1.2	15	12	10	1.8	1.5	0.3	0.3	5.32



$$\ell = (B/2) + \sqrt{5}\ (H+0.5) + 0.5 \quad m \qquad (8)$$

A sample of the measured and calculated pressures on both model and prototype, respectively, is shown in table (A-I) for B/H=4.

The actual total uplift force (T.U.F) acting on the half section of the canal lining can be calculated from the following formula using the data recorded in table (A-I):

$$T.U.F = \left[\sum_{1}^{10} P_p[c_H]_p + \sum_{11}^{n} P_p[C_I]_p\right] \quad ton/m' \quad (9)$$

where n is the total number of piezometers.
The critical thickness of lining, to resist the total uplift force can be expressed as follows:

$$C.T.L = (T.U.F)/(\ell.\gamma_c) \quad cm \qquad (10)$$

Analysis of experimental data

The purpose of study is to save costs of lining construction in canals of the shown situation in Figure (1). Therefore, relief valves are recommended to reduce some of the acting pressure on lining. To get the minimum value of pressure on lining, the optimum position of the valves is studied using four prototypes. A sample of the recorded and calculated pressure, P_m and P_p, respectively, is put in table (A-1) for B/H=4.

Table (2) shows values of the total uplift force (T.U.F) and the critical thickness of lining (C.T.L) for B/H=1.2, 2, 4 and 8, respectively, in case of opening four valves along the canal cross section.

Prototype No 1, B/H=4

It is clear from table (2) that, the minimum total uplift force can be found at the opening valves (5,7), (5,8), (5,9) and (5,10) and has the value 1.31, 1.79, 1.92 and 1.65 ton/m′ respectively, and the corresponding critical thickness of lining is 4.16, 5.7, 6.1 and 5.2 cm, respectively. The opened valves (5,7) give the minimum total uplift force and the minimum thickness of lining which equal 1.31 ton/m′and 6.14 cm, respectively. Valves (5,7) are located at b/B = 0.45 and S/L = 0.09 and it can be considered the optimal position for B/H=4, Table (3).

Prototype No 2, B/H=8

In this case the minimum total uplift force equals 2.81 and 2.83 ton/m′ and the corresponding critical thickness of lining equals 6.3 and 6.3 cm,as shown in Table (2). The difference in (T.U.F) in this case is not effective, therefore an equal (C.T.L) is obtained. The optimum horizontal position of valves (5,7) and (5,8) is located at b/B = 0.45 and 0.45, respectively. For the inclined position the corresponding S/L = 0.09 and 0.27, Table (3).

Prototype No 3, B/H=2

The working horizontal valves in this case are numbers 3,4,5 and 6, this is because of the reduction in model to satisfy B/H =2. The optimum position of valves is found at b/B=0.41 and S/L=0.08 which corresponds T.U.F=0.36 ton/m′ and C.T.L=1.55 cm, as shown in Table (2)

Prototype No 4, B/H=1.2

More reduction in the model is done to get (B/H=1.2, and two horizontal valves only are tested in this case. As shown in Table (2), the minimum (T.U.F) equals 0.97 ton/m′ and the corresponding (C.T.L) equals 8.3 cm at b/B = 0.47 and S/L = 0.27. The optimum position for each values of B/H analyzed above can be summarized in Table (3).

Table 2. values of the total uplift forces and critical thickness of lining in case of four opened valves along the canal cross section.

prototype No.	4		3		1		2	
B/H	1.2		2		4		8	
valves No.	T.U.F. ton/m′	C.T.L cm	T.U.F ton/m′	C.T.L cm	T.U.F. ton/m′	C.T.L. cm	T.U.F. ton/m′	C.T.L. cm
1,7	--	--	--	--	10.51	33	24.87	55.6
2,7	--	--	--	--	8.16	25.9	7.9	17.7
3,7	--	--	4.53	19.6	5.15	16.4	3.38	7.6
4,7	--	--	1.49	6.4	3.28	10.4	5.93	13.2
5,7	2.85	24.3	0.36	1.55	1.31	4.16	2.81	6.3
6,7	1.98	16.9	1.45	6.3	8.84	28.0	4.06	9.1
1,8	--	--	--	--	5.62	17.8	33.58	75
2,8	--	--	--	--	8.17	25.9	42.46	54.7
3,8	--	--	1.42	6.14	5.92	18.7	5.99	13.4
4,8	--	--	0.49	2.1	8.54	27.1	2.22	5
5,8	1.33	11.4	0.38	1.6	1.79	5.7	2.83	6.3
6,8	0.97	8.3	0.55	2.4	6.03	19.1	6.37	14.2
1,9	--	--	--	--	19.48	61.8	--	--
2,9	--	--	--	--	10.7	33.9	--	--
3,9	--	--	3.43	14.8	9.28	29.4	--	--
4,9	--	--	0.72	3.1	11.18	35.5	--	--
5,9	1.66	14.2	0.47	2	1.91	6.1	--	--
6,9	1.32	11.3	0.98	4.2	5.77	18.3	--	--
1,10	--	--	--	--	10.38	32.9	--	--
2,10	--	--	--	--	12.56	39.8	--	--
3,10	--	--	4.46	19.3	10.88	34.5	--	--
4,10	--	--	0.99	4.3	4.15	13.2	--	--
5,10	2.2	18.8	0.46	2	1.65	5.2	--	--
6,10	1.66	14.2	1.14	4.9	7.73	24.5	--	--

Table 3. Optimum position if four valves are used along the canal cross section.

B/H	1.2	2	4	8	8
T.U.F ton/m'	0.97	0.38	1.31	2.81	2.83
C.T.L cm	8.3	1.6	4.16	6.3	6.3
b/B	0.47	0.41	0.45	0.45	0.45
S/L	0.27	0.24	0.09	0.09	0.27

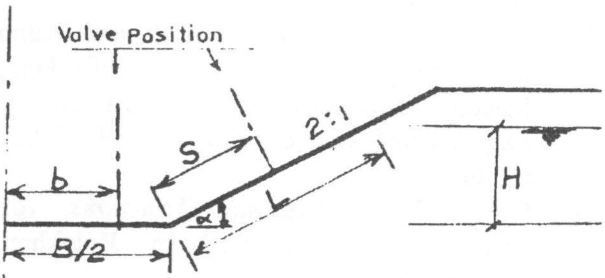


Figure 5. Canal Cross Section

From Table (3), the optimum position of the valves on both horizontal and side slope can be denoted by the term : b\B =0.45 and S/L =0.19, respectively. This means that to get the minimum value of uplift force and minimum thickness of lining, two valves must be constructed at b/B = 0.45 and another two at S/L = 0.19.

Study extended to compare the above work in Table (3) which include four valves along the canal cross section, with that of two valves only,Table(4), located at the same horizontal distance of the optimum position mentioned in Table (3)

Table 4. Values of (T.U.F) and (C.T.L) at the same horizontal distance of optimum position shown in Table 3, if two valves are used along the canal cross section.

B/H	1.2	2	4	8
T..U.F t/m'	2.07	0.44	2.08	3.3
C.T.L cm	17.7	1.9	6.6	7.4
b/B	0.47	0.41	0.45	0.45

It is evident from Tables (3 and 4) for B/H=2,4 and 8 that, there is no noticeable difference can be considered for use of two valves along the cross section instead of four valves, if comparison is made according to the required critical thickness of lining. It is also noticed from the comparison that, the calculated thickness of lining in the above two cases, Table (3 and 4), is less than that the actually constructed in field. Therefore for B/H 2,4 and 8, it can be recommended to use two valves along the cross section of the canal at b/B = 0.45, so that excess costs of the valve filter can be saved.

For B/H = 1.2 Tables (3,4), if two valves should be used, more increase in the thickness of lining about 1.13 is resulted than that obtained from using four valves. Then economical study must be done to give the best solution.

The following Table (5) indicates the required thickness of unreinforced portland cement concrete lining, based on the section capacity in ft^3/sec, Ref. [7]. The recommended thickness of lining shown in Table (5) is also less than the actually constructed in field.

Table 5. The recommended thickness of lining as given from Ref. [7], for unreinforced portland cement concrete.

B/H	1.2	2	4	8
Q ft^3/sec	254	1067	1906	3176
thickness of lining in inch	1.9	3	3.5	3.5
thickness of lining in cm	4.57	7.62	8.89	8.89

Canal velocity is assumed 1 m/sec = 3.28 ft/sec in calculating Q

CONCLUSIONS

1- For lining canals of the case under study, an experimental model is designed with a certain scale ratio.From the experimental results, the actual pressure on lining can be calculated from the deduced equation N<u>o</u> (4) and from which both of the total uplift force and critical thickness of lining can be evaluated using equations N<u>o</u> (9) and (10), respectively.
2- For B/H = 2,4 and 8; two relief valves can be used instead of four valves, along the canal cross section at optimum distance equals b/B = 0.45, to safe excess costs of the relief value filters.
3- For B/H = 1.2 and b/B = 0.47, an increase in the thickness of lining about 1.13 is resulted, if two valves are used instead of four valves, therefore evaluation study must be done to give the best economical solution.

RECOMMENDATIONS

1- The optimum valve distance in the longitudinal direction of flow in the lined canals must be studied.
2- Dimensions of the relief valve in the case study must be researched.

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APPENDIX (I)

Table (1-a) values of uplift pressure on both model and prototype, (P_m gm/cm^2) and (P_p t/m^2), respectively for B/H=4. [Using four valves along the canal cross section].

Valve No	1,7		2,7		3,7		4,7		5,7		6,7	
Piez. No	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p
1	8.0	0.94	8.0	0.94	7.4	0.66	6.7	0.44	4.8	0.15	8.2	1.06
2	8.7	1.42	8.0	0.94	7.7	0.79	7.3	0.62	5.1	0.18	8.5	1.26
3	8.7	1.42	8.0	0.94	7.9	0.88	7.3	0.62	5.1	0.18	8.5	1.26
4	8.7	1.42	8.2	1.06	7.7	0.79	7.3	0.62	5.3	0.20	8.4	1.19
5	8.7	1.42	8.2	1.06	7.7	0.79	7.1	0.55	5.3	0.20	8.4	1.19
6	8.7	1.42	8.2	1.06	7.6	0.74	6.7	0.44	5.0	0.17	8.3	1.12
7	8.6	1.34	8.2	1.06	7.2	0.59	6.1	0.32	5.0	0.17	8.2	1.06
8	8.5	1.26	8.2	1.06	7.3	0.62	6.4	0.37	5.0	0.17	8.2	1.06
9	8.5	1.26	8.2	1.06	7.0	0.52	6.1	0.32	5.0	0.17	8.2	1.06
10	8.5	1.26	8.2	1.06	7.3	0.62	6.4	0.37	5.0	0.17	8.2	1.06
11	8.5	1.15	8.2	0.96	7.2	0.51	6.0	0.25	5.3	0.16	8.2	0.96
12	8.5	0.95	8.0	0.67	6.8	0.30	6.0	0.17	5.3	0.11	8.2	0.77
13	8.4	0.70	8.2	0.60	7.4	0.33	6.5	0.17	5.3	0.08	8.2	0.60
14	8.5	0.57	8.2	0.45	7.4	0.22	6.5	0.11	5.3	0.05	8.2	0.44
15	8.5	0.41	8.2	0.31	7.4	0.14	6.5	0.07	5.3	0.02	8.2	0.31
16	8.5	0.26	8.2	0.19	7.4	0.09	6.5	0.03			8.2	0.19
17	8.7	0.20	8.2	0.12							8.2	0.11
18	8.8	0.11	8.2	0.05							8.2	0.04
19			8.2	0.01								
T.U.F. ton/m′		10.51		8.16		5.15		3.28		1.31		8.84
C.T.L. Cm		33		25.9		16.4		10.4		4.16		28

Both of T.U.F. and C.T.L. are calculated from Eqs. (9 and 10) respectively.

Table 1-b. values of uplift pressure on both model and prototype, (P_m gm/cm^2) and (P_p t/m^2), respectively for B/H=4.

Valve No	1,8		2,8		3,8		4,8		5,8		6,8	
	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p
1	7	0.53	7.8	0.48	7.5	0.70	8.0	1.94	5.2	0.20	7.6	0.75
2	7.5	0.70	8.1	1.0	7.7	0.79	8.3	1.12	5.5	0.34	7.8	0.84
3	7.6	0.75	8.3	1.12	7.7	0.79	8.3	1.19	5.7	0.30	8.0	0.94
4	7.6	0.75	8.2	1.06	7.7	0.79	8.4	1.19	5.7	0.26	7.8	0.84
5	7.6	0.75	8.2	1.06	7.6	0.75	8.3	1.19	5.7	0.26	7.8	0.84
6	7.6	0.75	8.2	1.06	7.6	0.75	8.2	1.12	5.5	0.26	7.7	0.79
7	7.6	0.75	8.2	1.06	7.6	0.75	8.2	1.06	5.4	0.22	7.7	0.79
8	7.6	0.75	8.2	1.06	7.6	0.75	8.2	1.06	5.4	0.22	7.6	0.75
9	7.4	0.66	8.0	1.94	7.5	0.70	8.0	0.94	5.4	0.20	7.5	0.70
10	7.6	0.75	8.1	1.0	7.7	0.79	8.2	1.06	5.3	0.20	7.6	0.75
11	7.7	0.70	8.3	1.02	8.0	0.84	8.3	1.02	5.3	0.20	7.7	0.70
12	7.7	0.45	8.1	0.72	7.4	0.45	8.3	0.83	5.6	0.14	7.4	0.45
13	7.4	0.41	8.1	0.56	7.6	0.38	8.0	0.52	5.6	0.10	7.5	0.36
14	7.7	0.29	8.2	0.45	7.6	0.28	8.0	0.38	5.6	0.06	7.5	0.25
15	7.7	0.20	8.2	0.31	7.6	0.18	8.0	0.26	5.6	0.03	7.5	0.16
16	7.7	0.12	8.2	0.20	7.6	0.10	8.2	0.20			7.5	0.09
17	7.7	0.06	8.2	0.10	7.7	0.06	8.2	0.10			7.5	0.05
18	7.7	0.02	8.2	0.05	7.7	0.02	8.2	0.05				
T.U.F. ton/m'		5.62		8.17		5.92		8.54		1.79		6.03
C.T.L. Cm		17.8		25.9		18.7		27.1		5.7		19.1

Table (1-c) values of uplift pressure on both model and prototype, (P_m gm/cm^2) and (P_p t/m^2), respectively for B/H=4.

Valve No	1,9		2,9		3,9		4,9		5,9		6,9	
Piez. No	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p
1	9.1	1.79	8.3	1.12	8.0	0.94	8.0	0.94	5.4	0.22	7.6	0.74
2	9.5	2.26	8.4	1.19	8.3	1.12	8.4	1.19	5.6	0.24	7.8	0.83
3	9.6	2.4	8.5	1.26	8.3	1.12	8.7	1.42	5.7	0.26	7.7	0.79
4	9.7	2.5	8.5	1.26	8.3	1.12	8.9	1.60	6.0	0.30	7.7	0.79
5	9.7	2.5	8.5	1.26	8.3	1.12	8.8	1.50	6.1	0.32	7.7	0.79
6	9.7	2.5	8.7	1.42	8.3	1.12	8.8	1.50	5.6	0.24	7.7	0.79
7	9.5	2.26	8.6	1.34	8.3	1.12	8.7	1.42	5.5	0.23	7.7	0.79
8	9.5	2.26	8.6	1.34	8.3	1.12	8.7	1.42	5.5	0.23	7.6	0.74
9	9.5	2.26	8.6	1.34	8.3	1.12	8.6	1.34	5.5	0.23	7.3	0.62
10	9.5	2.26	8.6	1.34	8.4	1.19	8.6	1.34	5.5	0.23	7.3	0.62
11	9.4	2.01	8.7	1.46	8.5	1.16	8.8	1.40	5.8	0.23	7.8	0.75
12	9.5	1.87	8.6	1.01	8.5	0.95	8.7	1.09	6.0	0.19	7.4	0.45
13	9.4	1.50	8.6	1.81	8.5	0.76	8.6	0.81	6.0	0.12	7.5	0.36
14	9.4	1.25	8.6	0.63	8.5	0.58	8.6	0.63	6.0	0.08	7.5	0.26
15	9.4	1.02	8.6	0.45	8.5	0.41	8.6	0.45	6.0	0.04	7.5	0.16
16	9.4	0.77	8.6	0.31	8.5	0.28	8.6	0.31	6.0	0.02	7.5	0.09
17	9.4	0.55	8.6	0.18	8.5	0.16	8.6	0.18			7.5	0.04
18	9.4	0.35	8.6	0.09	8.5	0.08	8.6	0.09				
19	9.4	0.16										
T.U.F. ton/m'		19.48		10.7		9.28		11.18		1.91		5.77
C.T.L. Cm		61.8		33.9		29.4		35.5		6.1		18.3

Table (1-d) values of uplift pressure on both model and prototype, (P_m gm/cm^2) and (P_p t/m^2), respectively for B/H=4.

Valve No	1,10		2,10		3,10		4,10		5,10		6,10	
Piez. No	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p
1	8.0	0.49	8.4	1.19	8.2	1.06	7.6	0.44	5.0	0.17	7.4	0.66
2	8.4	1.19	8.7	1.42	8.4	1.19	7.0	0.53	5.5	0.23	8.0	0.94
3	8.4	1.19	8.7	1.42	8.6	1.34	7.2	0.59	5.5	0.23	8.2	1.06
4	8.4	1.19	8.8	1.50	8.6	1.34	7.3	0.62	5.7	0.26	8.3	1.12
5	8.4	1.19	8.8	1.50	8.6	1.34	7.2	0.59	5.6	0.24	8.1	1.0
6	8.6	1.34	8.8	1.50	8.6	1.34	7.0	0.53	5.5	0.23	8.2	1.06
7	8.6	1.34	8.8	1.50	8.6	1.34	6.8	0.47	5.4	0.22	8.2	1.06
8	8.6	1.34	8.8	1.50	8.6	1.34	7.0	0.53	5.5	0.23	8.0	0.94
9	8.4	1.19	8.7	1.42	8.6	1.34	6.7	0.44	5.2	0.19	8.0	0.94
10	8.6	1.34	8.8	1.50	8.6	1.34	7.0	0.53	5.5	0.23	8.0	0.94
11	8.7	1.30	9.0	1.57	8.7	1.30	7.3	0.56	5.5	0.20	8.2	0.96
12	8.6	1.02	9.0	1.34	8.7	1.10	7.2	0.40	5.4	0.13	8.1	0.73
13	8.7	0.88	8.8	0.95	8.7	0.88	7.0	0.26	5.5	0.09	8.0	0.54
14	8.7	0.69	9.0	0.89	8.7	0.69	7.2	0.20	5.6	0.06	8.0	0.38
15	8.7	0.50	9.0	0.68	8.7	0.50	7.2	0.12	5.6	0.03	8.0	0.26
16	8.7	0.35	9.0	0.49	8.7	0.35	7.2	0.07			8.0	0.17
17	8.7	0.21	9.0	0.31	8.7	0.21	7.2	0.03			8.0	0.08
18	8.7	0.10	9.0	0.16	8.7	0.10					8.0	0.03
19			9.0	0.07	8.7	0.03						
T.U.F. ton/m'		10.38		12.56		10.88		4.15		1.65		7.73
C.T.L. Cm		32.9		39.8		34.5		13.2		5.2		24.5

Table (1-e) values of uplift pressure on both model and prototype, (P_m gm/cm^2) and (P_p t/m^2), respectively for B/H=4.

b/B	0.47		0.41		0.45		0.45	
B/H	1.2		2		4		8	
piez No	P_m	P_p	P_m	P_p	P_m	P_p	P_m	P_p
1					5.6	0.24	3.0	0.17
2					5.8	0.27	3.4	0.27
3					5.9	0.29	3.5	0.31
4					6.0	0.30	3.5	0.31
5					6.0	0.30	3.5	0.31
6			4.4	0.11	5.8	0.27	3.4	0.27
7			4.4	0.11	5.8	0.27	3.3	0.24
8	8.0	0.64	4.5	0.12	5.8	0.27	3.3	0.24
9	8.0	0.64	4.6	0.12	5.7	0.26	3.3	0.24
10	8.0	0.64	4.5	0.12	5.8	0.27	3.3	0.24
11	8.4	0.72	4.7	0.11	6.0	0.26	3.4	0.20
12	8.5	0.63	5.0	0.09	6.0	0.19	3.4	0.10
13	9.5	0.89	5.3	0.07	6.0	0.12		
14	9.5	0.77	5.3	0.03	6.1	0.09		
15	9.5	0.64			6.1	0.05		
16	9.5	0.50			6.1	0.02		
17	9.5	0.38						
18	9.5	0.27						
19	9.5	0.15						
20	9.5	0.05						
T.U.F ton/m'		2.07		0.44		2.08		3.3
C.T.L cm		17.7		1.9		6.6		7.4

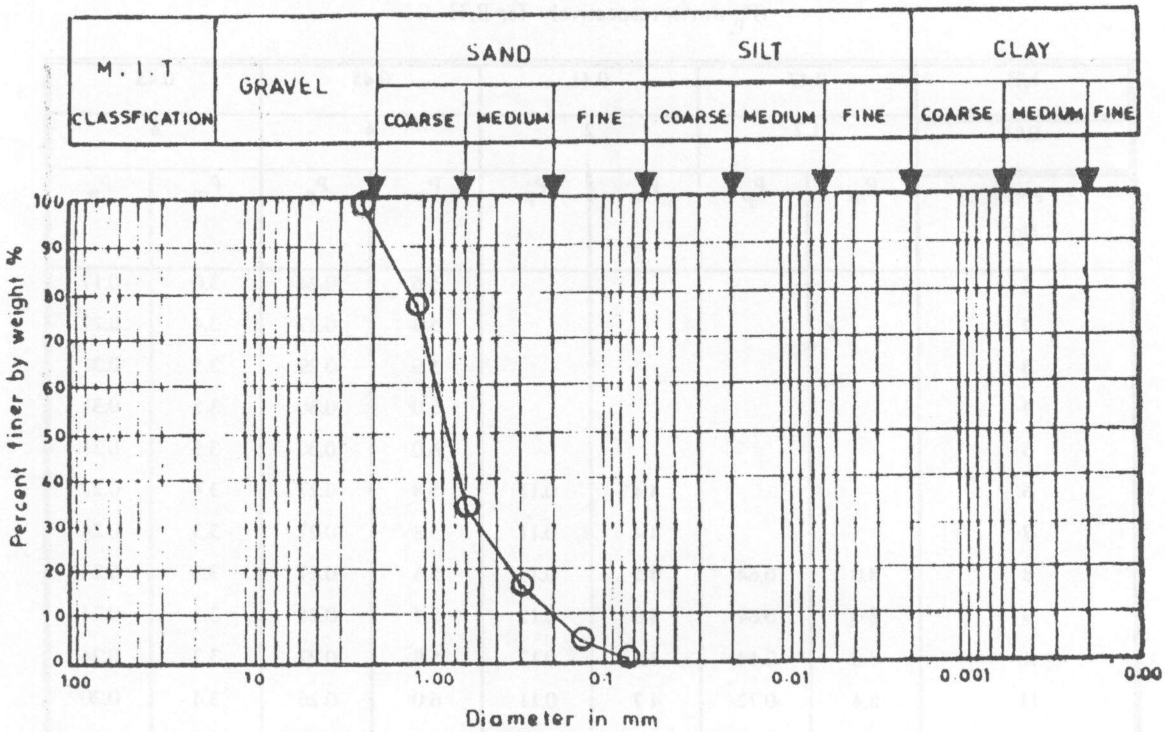

Figure (1_Appendix) Sieve Analysis for the Used Sand.

Table (3). Values of γ_s & K_m as Examined in the Laboratory of Soil Mechanics in the Faculty of Eng., ALex. Univ.

$\gamma_s t/m^3$	K_m Cm/Sec.
1.586	3.47 $(10)^{-4}$
1.690	2.50 $(10)^{-4}$
1.798	2.04 $(10)^{-4}$