UPLIFT PRESSURE ON WEIRS.

A Floor with a Line of Sheet Piles.

By V. I. Vaidhianathan, Gurdas Ram
and
E. McKenzie Taylor.
(*From the Irrigation Research Institute, Lahore.*)

Received November 20, 1935.

Introduction.

In two previous publications,[1, 2] an account has been given of the estimation of uplift pressure on weirs built on permeable foundations, by means of the potential distribution. The technique of the method has been described in the papers referred to above. It was definitely established in those papers, *that the law of subsoil flow is analogous to the distribution of potential which governs the flow of electricity in a conductor.* Having once established this fact, it became possible to employ the method to find the pressure distribution in any design of structure and to formulate laws for the various cases. The results are of immense practical importance for purposes of design. A knowledge of the uplift pressure under weirs is necessary, since, if they are not constructed to withstand the pressures, failures such as have occurred in the past may be repeated. Though the problem is extremely important from an engineering standpoint, yet these experiments offer a wide scope for theoretical research as well. The two cases dealt with in this paper are, a flush floor with different lengths of sheet pile at the upstream end, and a depressed floor with different lengths of sheet pile at the upstream end.

Results.

In the first series of experiments with a flush floor, the model was 12″ long and the lengths of the sheet pile were 1″, 2″, 3″, 4″, 5″ and 6″, thus giving the ratio of the floor length to sheet pile as 12, 6, 4, 3, 12/5, 2. This ratio is denoted by α in the paper.

(*a*) The pressure contours for the case when different lengths of sheet pile are introduced at the upstream end of a flush floor, maintaining the length of the floor constant, are given in Fig. 1. The different curves are for decrements of 5% of the total difference of pressure between the upstream and the downstream. In addition to these 5% lines, those indicating the percentage pressures at various important points, such as the end of the sheet pile and the beginning of the floor, are also marked in the figure.

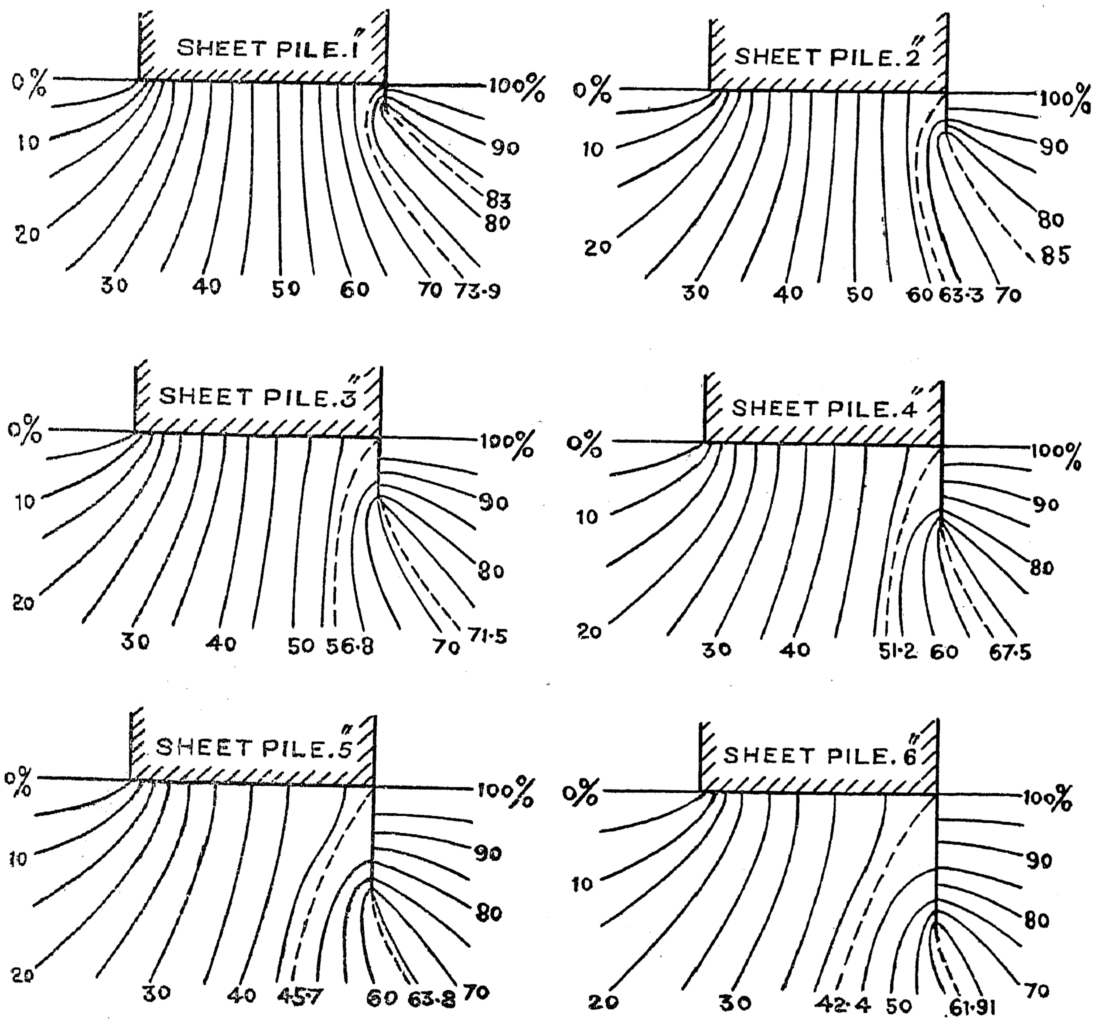

FIG. 1.

Pressure Contours—Flush Floor 12″.

(*b*) In Fig. 2 the percentage pressure along the floor is plotted against fractional distance for various values of α. By fractional distance is meant, the ratio of the distance from the beginning of the floor to the total length of the floor.

This case has been theoretically worked out by Prof. Weaver.[3] Fig. 2 shows also the comparison between the theoretical results according to Weaver and the experimental values. It is clear from this figure that theory and experiment are in accord.

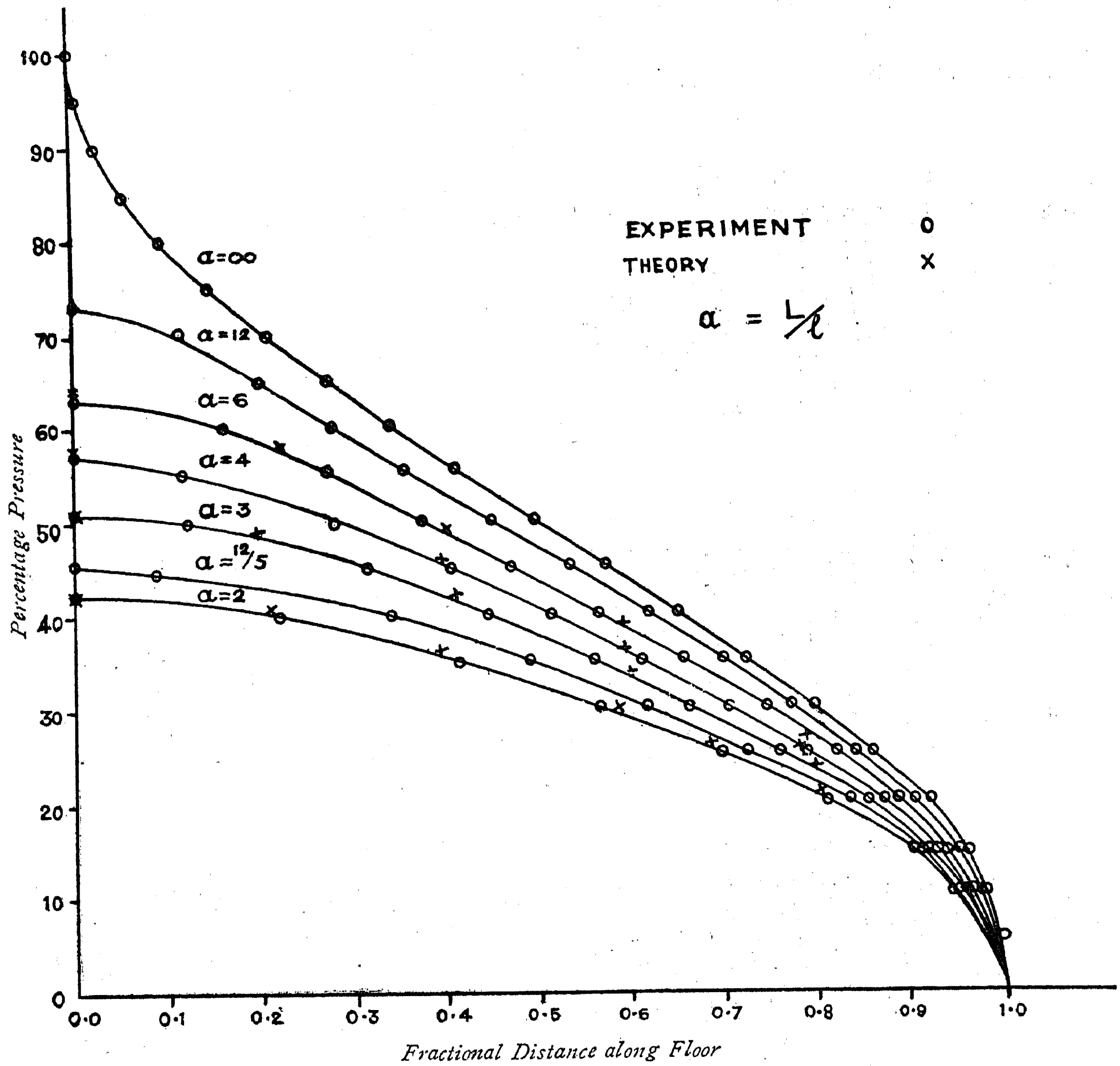

FIG. 2.

Pressure Distribution along Flush Floor.

(c) The variations of pressure at the points A and B of the structure for varying lengths of sheet piles are shown in Fig. 3. The corresponding values of α are also plotted along the abscissa. The positions of A and B are shown in the inset. The equations for these curves, giving the percentage pressure at A and B for any value of α, derived from theoretical considerations are[3]

$$\text{Cos}\left(\frac{\pi P_A}{100}\right) = \frac{1-\lambda}{\lambda}$$

$$\text{Cos}\left(\frac{\pi P_B}{100}\right) = \frac{2}{\lambda} - 1$$

$$\lambda = \frac{1 + \sqrt{1+a^2}}{2}$$

$$a = \frac{L}{l}$$

Here l is the length of sheet pile, and L is the length of floor.

Pressures calculated according to these equations are also plotted in Fig. 3. They lie along the experimental curve.

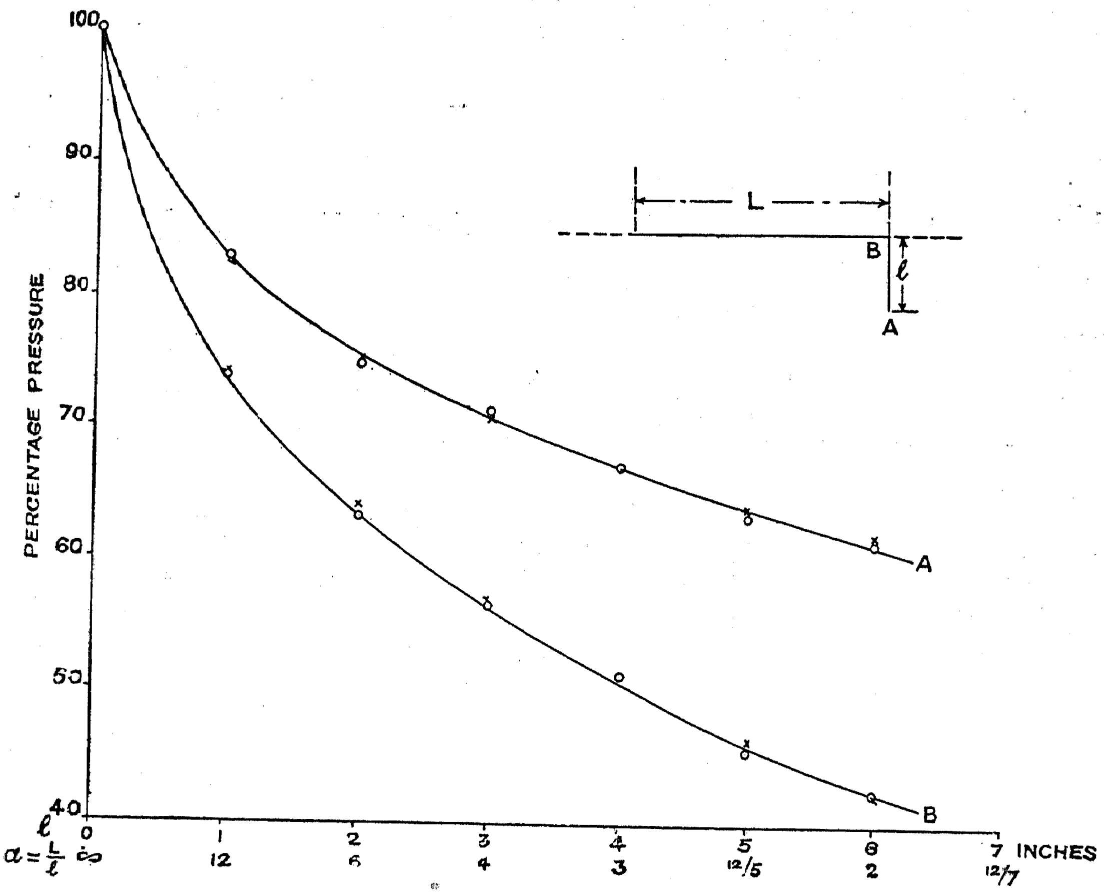

FIG. 3.

Pressures at A and B under Flush Floor.

It can be seen from this figure that to begin with, the curve is steep, gradually becoming flatter as a decreases. This means that unit increase in the length of the sheet pile, cuts off more pressure when the sheet pile is short, than when the sheet pile is long. In other words, the effectiveness of a sheet pile in cutting off pressure decreases with increase in length. A chart is given in Tables I and II showing the pressure at A and B for various values of $\frac{1}{\alpha}$.

(d) In the next series of experiments the floor of the model was 12″ in length and it was depressed by 2″, giving a ratio of depression to width, of $\frac{1}{6}$. With this floor, 6 sheet piles of different lengths as 1″, 2″, 3″, 4″, 5″ and 6″ were investigated thus giving values of α_1* ; as 12, 6, 4, 3, 12/5, 2.

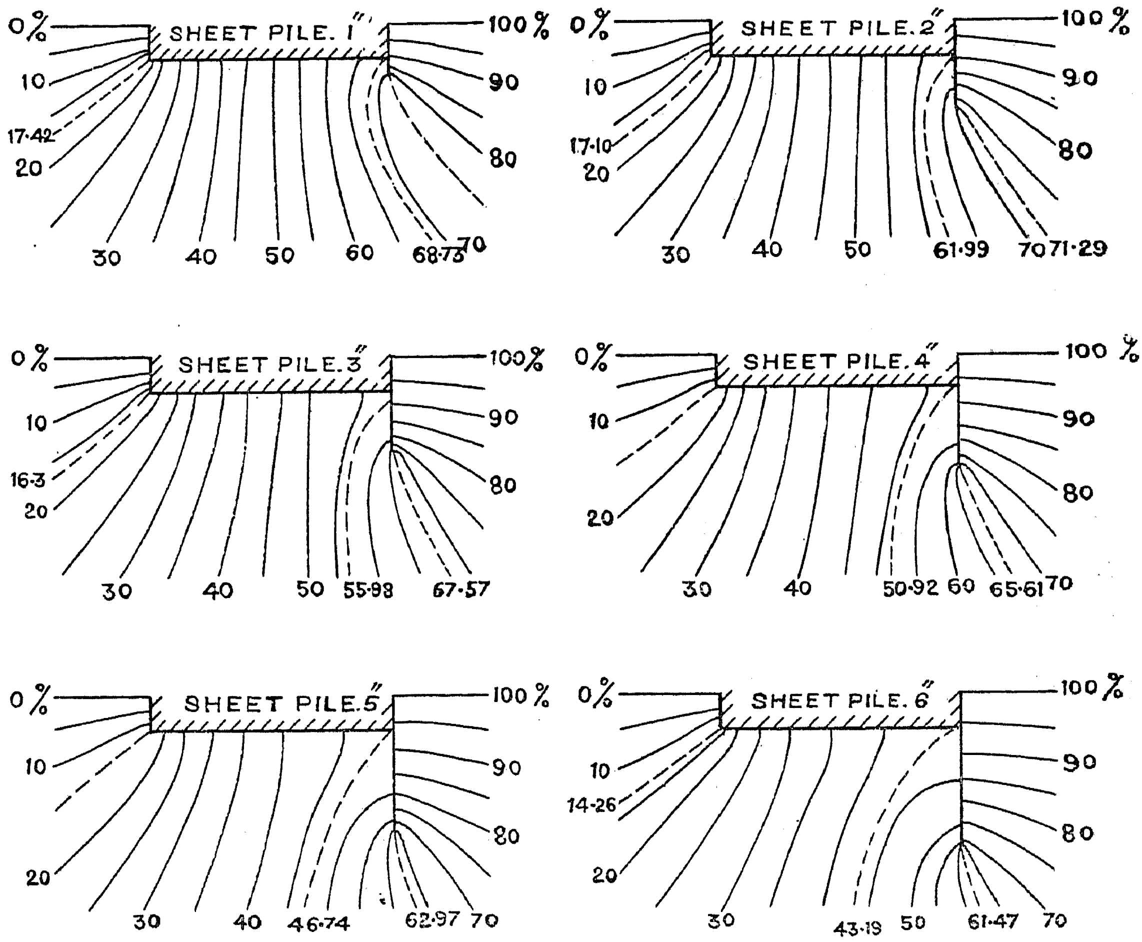

FIG. 4.

Pressure Contours—12″ Floor Depressed 2″.

The pressure contours for the six sets in this case are shown in Fig. 4. The lines are for decrements of 5 % of the total difference of pressure between the upstream and the downstream. In addition to these, the lines at important points of the work such as the end of the sheet pile, the corner of the

* $\alpha_1 = \frac{L}{l_1}$ See inset in Fig. 6.

sheet pile and the floor, and the horizontal part of the depressed floor are also shown in the figure.

(*e*) The percentage pressure distribution along the floor in the depressed case is plotted against the fractional distance in Fig. 5, for various values of a_1*. This case is similar to that shown in Fig. 2 for the flush floor. The theoretical solution for the case of the depressed floor has not so far been obtained and hence, a comparison of the experimental with the theoretical is not possible at present.

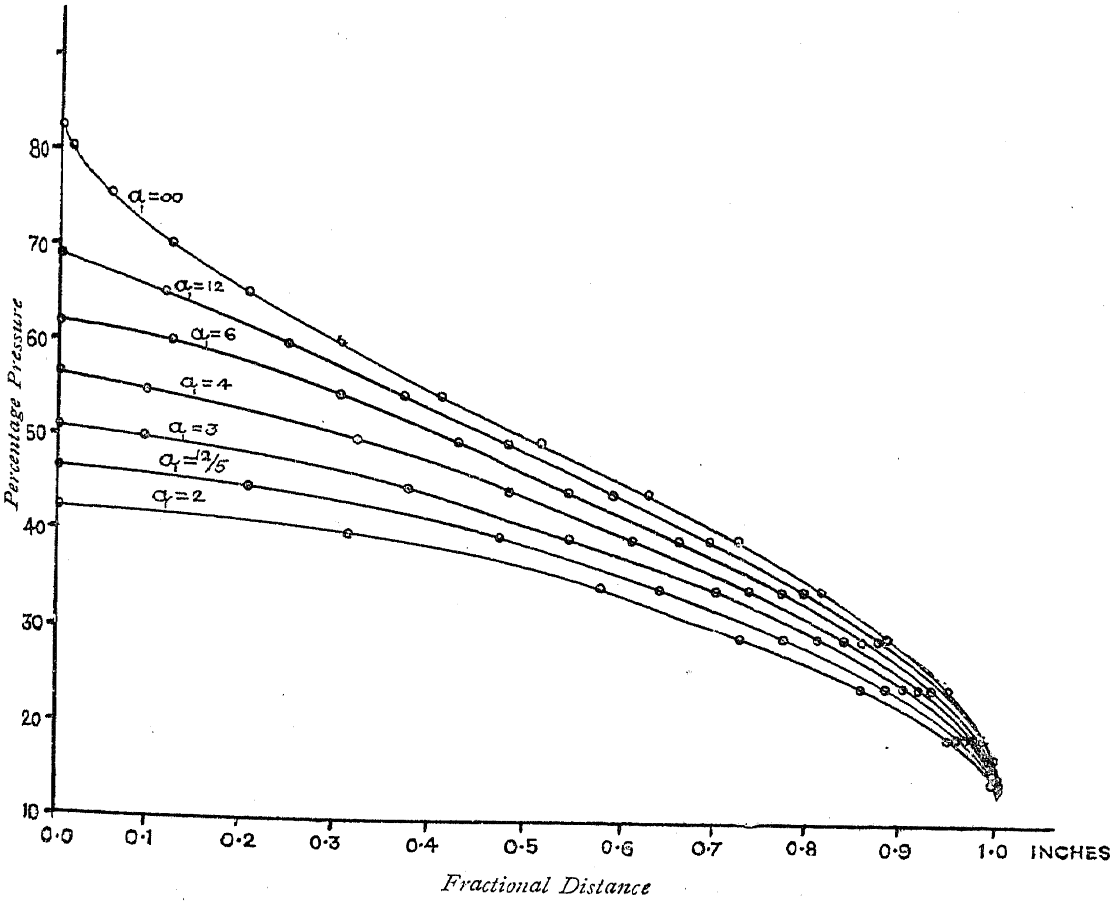

FIG. 5.

Pressure Distribution along Depressed Floor.

(*f*) In Fig. 6, the percentage pressure at A, B and on B–C are plotted as a function of the length of the sheet pile in the depressed case. For the position of the points A, B and C, see inset. A chart showing the values of P_A, P_B and P_{B-C} is given in Tables III, IV and V. The pressures at these points for any value of $\frac{l_2}{L}$ can be read from the chart, where l_2 is the length of the sheet pile including the two inches of the depression, and L is the length of the floor.

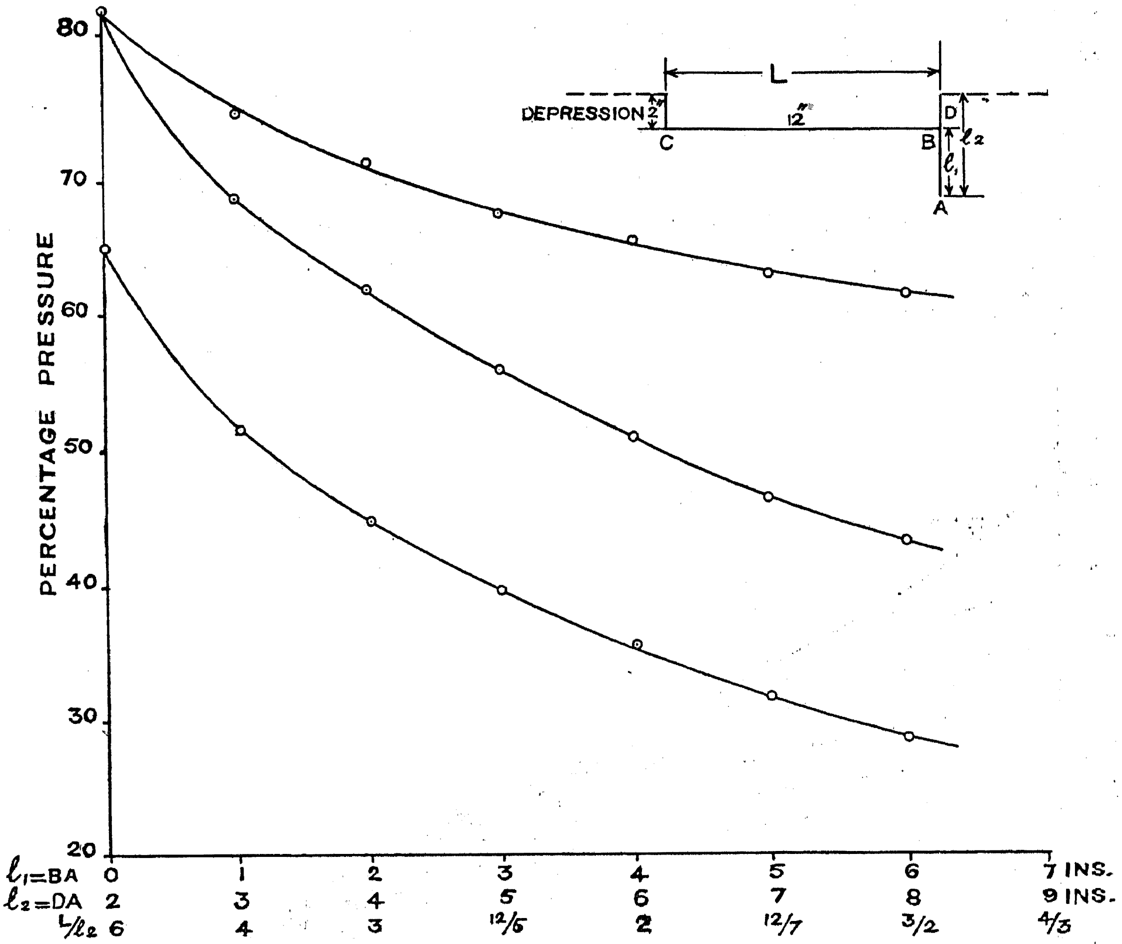

FIG. 6.

Pressures at A, B, and on B—C.

For the case of the depressed floor, a comparison with the values of the hydraulic method has been made. The results of the two methods agree when the sheet piles are long. But when the sheet piles are short, there is a difference of about 7% between the results of the two methods. This is due to the fact that in the hydraulic method, the sheet pile had a thickness of about half an inch which becomes comparable to the length of the pile when it is short. Also, the tubes inserted for measurement of pressures in the hydraulic method had a diameter of about quarter of an inch which becomes comparable to the length of the pile when it is short.

Summary.

The electrical method has been employed to determine the pressure distribution under models of weirs when different lengths of sheet pile have been introduced. One model had a 12″ flush floor and the lengths of the sheet piles introduced were 1″, 2″, 3″, 4″, 5″ and 6″. The complete systems

TABLE I. FLUSH FLOOR.

(See also Fig. 3.)

Table showing Values of P_A for Values of l/L

(Ratio of length of sheet pile to length of floor).

	·00	·01	·02	·03	·04	·05	·06	·07	·08	·09
·00	100·0	93·6	91·1	89·1	87·5	86·0	84·8	83·6	82·6	81·5
·10	80·6	79·7	78·9	78·1	77·3	76·6	75·9	75·2	74·6	74·0
·20	73·4	72·9	72·4	71·9	71·4	70·9	70·5	70·0	69·6	69·1
·30	68·7	68·3	67·9	67·5	67·2	66·8	66·5	66·1	65·8	65·5
·40	65·2	64·8	64·5	64·2	64·0	63·7	63·4	63·2	62·9	62·7
·50	62·5	62·2	62·0	61·8	61·6	61·4	61·2	61·0	60·8	60·6
·60	60·4	60·2	60·0	59·8	59·7	59·5	59·3	59·2	59·0	58·9
·70	58·7	58·6	58·4	58·3	58·2	58·0	57·9	57·8	57·6	57·5
·80	57·4	57·3	57·2	57·1	56·9	56·8	56·7	56·6	56·5	56·4
·90	56·3	56·2	56·2	56·1	56·0	55·9	55·8	55·7	55·7	55·6
1·00	55·5	55·4	55·3	55·3	55·2	55·1	55·1	55·0	55·0	54·9

TABLE II. FLUSH FLOOR.

(See also Fig. 3.)

Table showing Values of P_B for Values of l/L

(Ratio of length of sheet pile to length of floor).

	·00	·01	·02	·03	·04	·05	·06	·07	·08	·09
·00	100·00	91·3	87·4	84·5	82·1	80·0	78·1	76·5	74·9	73·5
·10	72·1	70·8	69·6	68·4	67·2	66·1	65·1	64·0	63·0	62·1
·20	61·2	60·3	59·4	58·6	57·8	57·1	56·4	55·6	54·9	54·2
·30	53·5	52·8	52·2	51·5	50·8	50·2	49·6	49·0	48·4	47·9
·40	47·4	46·8	46·3	45·8	45·2	44·8	44·3	43·8	43·3	42·8
·50	42·4	42·0	41·6	41·2	40·8	40·3	39·9	39·5	39·1	38·7
·60	38·3	37·9	37·6	37·2	36·8	36·5	36·2	35·8	35·5	35·2
·70	34·8	34·5	34·2	33·9	33·6	33·3	33·0	32·7	32·4	32·2
·80	31·9	31·7	31·4	31·2	30·9	30·7	30·4	30·2	29·9	29·7
·90	29·4	29·2	28·9	28·7	28·5	28·2	28·0	27·8	27·6	27·4
1·00	27·2	26·9	26·7	26·5	26·4	26·2	26·0	25·8	25·6	25·4

of equi-pressure lines and the variations of pressure at the ends of the sheet pile, and the corner of the sheet pile and floor are given in Figs. 1, 2, and 3. Charts showing the variations of pressure at the two latter points are given in Tables I and II. The theoretical equations obtained by Weaver, for the pressure distribution in the analogous cases, have been verified and are found to be in accord with the experimental results. Another model had a 12″ floor with a depression of 2″. Sheet piles of 1″, 2″, 3″, 4″, 5″ and 6″ were

TABLE III. DEPRESSED FLOOR.

(See also Fig. 6.)

Table showing the Values of P_A for Values of l_2/L
(Ratio of length of sheet pile to length of floor).

	Ratio of depression to length of floor 1/6									
	·00	·01	·02	·03	·04	·05	·06	·07	·08	·09
·10								82·1	81·1	80·1
·20	79·2	78·3	77·5	76·8	76·1	75·4	74·8	74·2	73·6	73·0
·30	72·5	72·0	71·5	71·1	70·6	70·2	69·8	69·4	69·0	68·6
·40	68·2	67·9	67·5	67·2	66·8	66·5	66·2	65·9	65·6	65·3
·50	65·0	64·8	64·5	64·3	64·1	63·8	63·6	63·4	63·2	63·0
·60	62·8	62·6	62·4	62·2	62·0	61·9	61·7	61·5	61·4	61·2

TABLE IV. DEPRESSED FLOOR.

(See also Fig. 6.)

Table showing the Values of P_B for Values of l_2/L
(Ratio of length of sheet pile to length of floor).

	Ratio of depression to length of floor 1/6									
	·00	·01	·02	·03	·04	·05	·06	·07	·08	·09
·10								81·4	78·9	77·0
·20	75·3	73·8	72·3	71·1	69·9	68·7	67·7	66·7	65·8	64·9
·30	64·0	63·2	62·4	61·6	60·9	60·2	59·5	58·8	58·1	57·4
·40	56·8	56·1	55·5	54·9	54·3	53·7	53·1	52·5	51·9	51·4
·50	50·8	50·3	49·7	49·2	48·7	48·2	47·7	47·3	46·8	46·4
·60	45·9	45·5	45·1	44·7	44·3	43·9	43·5	43·1	42·7	42·3

TABLE V. DEPRESSED FLOOR.

(See also Fig. 6.)

Table showing Values of P_{B-C} for Values of l_2/L

(Ratio of length of sheet pile to length of floor).

	Ratio of depression to length of floor 1/6									
	·00	·01	·02	·03	·04	·05	·06	·07	·08	·09
·10								64·1	61·8	59·9
·20	58·2	56·7	55·4	54·2	53·0	52·0	50·9	50·0	49·1	48·2
·30	47·4	46·6	45·9	45·2	44·5	43·8	43·1	42·5	41·9	41·2
·40	40·6	40·1	39·5	38·9	38·3	37·8	37·2	36·7	36·2	35·7
·50	35·2	34·7	34·2	33·7	33·2	32·8	32·4	32·0	31·6	31·2
·60	30·9	30·5	30·2	29·9	29·6	29·3	29·0	28·8	28·5	28·3

fixed to this depressed floor and the pressure distributions at the end of the sheet pile, at the corner of the sheet pile and floor, and on the horizontal part of the masonry floor have also been investigated. The results are given in Figs. 4, 5, and 6. Charts showing the pressure distribution at the various points mentioned above are given in Tables III, IV, and V. With the help of the tables, it is now possible to determine the pressure under simple cases of weirs dealt with, and, hence, works can be designed to withstand the pressures. More complicated cases are under investigation.

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1751-35.—Printed at The Bangalore Press, Mysore Road, Bangalore City, by T. Subramania Aiyar, Superintendent, and Published by The Indian Academy of Sciences, Indian Institute of Science, Bangalore