EXPERIMENTAL STUDY FOR THE EFFECT OF SEEPAGE PAST HYDRAULIC STRUCTURES ON THE UPLIFT PRESSURE ALONG THE FLOOR

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ABSTRACT

An experimental study is presented to investigate the effect of seepage behind side walls of hydraulic structures on the uplift pressure along the under-side of the floor. The effect of the ratio between the floor width b and the length L on the uplift pressure was investigated. Experiments were carried out using the sand model. Curves describe the influence of the side free seepage on pressures are given for the floor without sheetpiling case and floor with sheetpiling case.

NOTATIONS

b	width of the floor
H	total effective head
h	potential head at any point along the floor
h_f	elevation of the phreatic surface above the floor level
L	length of the floor
l	distance between the sheetpile and the upstream edge of the floor
S_1	depth of the intermediate sheetpile
S_2	depth of the end sheetpile
t	thickness of the floor

INTRODUCTION

Water retaining head structures are usually provided by side abutments and walls, through which the structure adjoins the permeable bank earth. Behind these walls and abutments on the side of earth bank, the water percolates through the earth fill from the upstream towards the downstream side of structure creating a free seepage area. The side seepage flow in this case is defined as seepage past structure.

For the same effective head, the seepage flow in the zone of structure follows two ways. The first way is the confined seepage through the permeable foundation layer beneath the structure floor. This confined seepage produces uplift pressures along the under-side of the floor. The second way is the free seepage through the earth fill behind the walls creating a hydrostatic pressure on the walls. In major hydraulic structures, specially pump stations, the side seepage from the delivery side causes erosion on the canal sides at the suction zone.

The free seepage pressure on the longitudinal wall is higher than the confined seepage pressure. This cause the underground water to flow laterally from the abutment toward the longitudinal axis of the structure, which presents a complicated three dimensional problem.

In the present design procedures for the floors of the hydraulic structures, the uplift forces due to the confined seepage beneath these floors are only considered. Neglecting the effect of the side seepage on the uplift pressures and exit gradients leads to inaccurate design for the structure floor. Furthermore, these pressures are assumed to be uniformly distributed on the lateral direction, which does not simulate actual distribution.

Figure (1) shows definition sketches to illustrate the effect of the side seepage behind regulator's wall. In Figure (1-b), the longitudinal section 1-1 demonstrates the phreatic surface of the side seepage. While section 2-2 shows the uplift pressure distribution along the floor axis due to the confined seepage. Considering section 4-4 normal to the floor direction, the elevation of the phreatic surface above the floor level h_f is higher than the ordinate of the uplift pressure along the floor h. This causes an increase in the uplift pressure acting on the floor as compared with that obtained for plan problem.

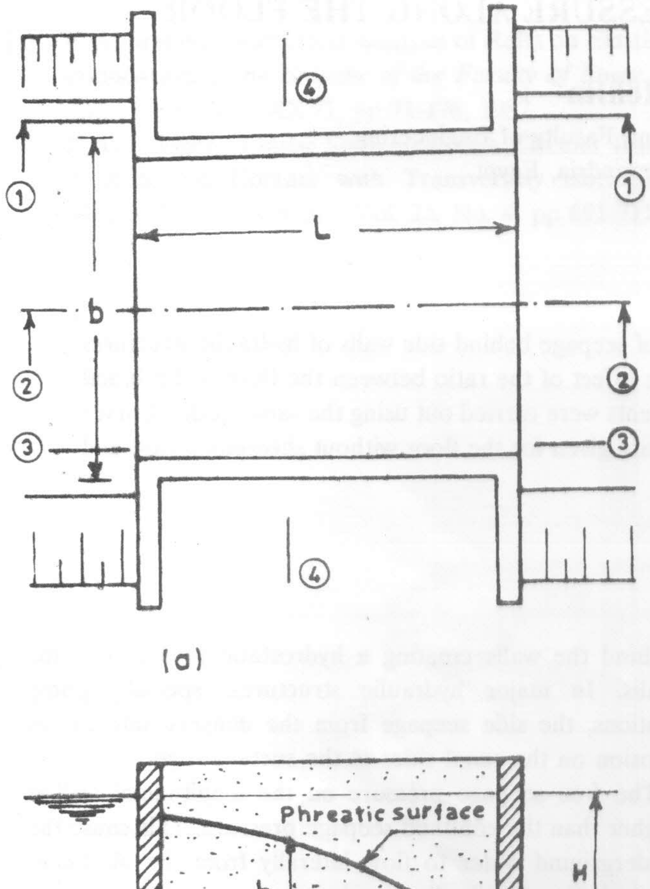

Figure 1. Definition sketches;
a- plane, b) phreactic surface b- uplift pressure diagram.

The problem of seepage past structures is not sufficiently studied to reflect its importance in the design considerations. In some literatures, a general definition for the problem concerning the calculations of seepage quantity and construction of phreatic surface due to the side seepage was presented [1,2,3,4]. In other literatures, analysis are given for structures with sheetpiling walls extend normally from the abutments in plan [5].

The effect of the side seepage on the uplift pressure along the floors of retaining head structures has not been investigated.

The present study is intended to investigate the effect of the side seepage on the uplift pressures for different values for the ratio of the floor width b to the length L. The experimental study concerned with structures' floor with and without sheetpiling.

EXPERIMENTAL PROCEDURE

Both free and confined seepages in zone of structure occur at the same time which presents a spatial seepage problem appears to be non-tractable by theoretical solutions. Therefore, the problem was decided to be investigated using the experimental sand model.

The experimental model consists of the main tank (1) and the constant head tank (2) as shown in Figure (2). The main tank has two prespex faces (3) 140 x 70 x 1.2 cm, and two steel plate sides (4) each of 102 x 70 x 0.3 cm. The tank is provided with two tubes (5), the first one used to escape the percolating water at the downstream side, and the second one is to collect the overflowing water from the upstream side. The main tank was fed from the constant head tank through the pipe (6). The constant head tank has internal dimensions equal to 30 x 30 x 50 cm.

The structure model was made of prespex. It consists of two side walls (7) and the floor (8). The side walls extend 5.0 cm normal to the flow direction. The floor is 30 cm length and 2.5 cm thickness.

The pressure on the under-side of the floor model were measured by a grid of piezometers (9). The piezometers are spaced by 5.0 cm in the direction of the floor length and 7.5 cm normal to it. The glass pipes piezometers have 0.6 cm diameter were installed vertically on the floor model.

The sand filling (10) was chosen as a porous medium. It has an average grains diameter varies from 0.4 to 2.0 mm. The thickness of the sand layer was constant and equals to 40 cm in all the experiments. For each experiment, the sand was compacted in layers each 10 cm thickness using steel hammer. The compaction's system was kept constant in all experiments to insure constant permeability of sand in all tests.

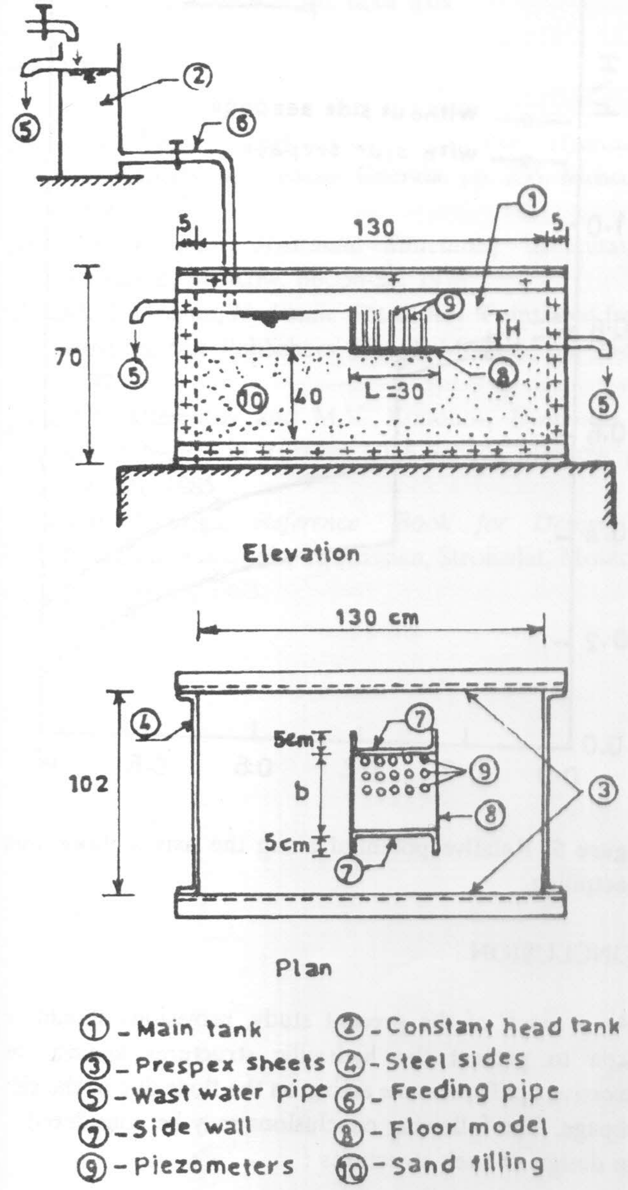

Figure 2. Experimental model.

The experiments were conducted by mounting the floor model without sheetpiles on the sand. The floor has a constant length L equal to 30 cm, and initial width b of 100 cm. First, the uplift pressures were measured by piezometers for the case of no side seepage by extending the floor width to the entire width of the main tank. Then, the width of floor was reduced to be 90, 78, 63.5, 48,5, 33 and 18 cm giving a ratio of b/L equals to 3.0, 2.6,2.1, 1.6, 1.1 and 0.6, respectively. For each width, the space between the model walls and the face of the main tank was filled by sand. The upstream water was retained by vertical wall fixed to upstream edge of the floor.

Considering a value of $b/L = 0.6$, one experiment only was carried out for floor with sheetpile. Two sheetpiles were fixed to the under-side of floor. The first has a depth of 7.5 cm located at a distance l equal to 10 cm from the upstream end. The other sheetpile has depth equals to 2.0 cm and placed at the down stream end.

ANALYSIS OF THE RESULTS

The experimental results indicate that the side seepage has a remarkable effect on the confined seepage characteristics beneath the floor as follows :

For floor without sheetpiles, the value of the potential along the floor axis were obtained considering no side seepage. Allowing side seepage it causes an increase in the potential values on the floor as shown in Figure (3). This increase appears to be negligible for values of $b/L > 2.6$. For $b/L = 3.0$, the potentials are increased by values vary between (2-7%). Decreasing the ratio b/L leads to remarkable increase in potential values. For b/L equals to 2.6, 2.1, 1.6, 1.1 and 0.6 the values of potential increase by (4-14%), (8-20%), (12-38%), (17-45%) and (20-50%), respectively. From Figure (3) it is clear that, the loss of potential at the downstream of the floor is higher than that at the upstream. On the other hand this effect increases as we move towards the side walls. Figure (4) shows an increase in the potential values at the longitudinal section 3-3 Figure (1-a), which is located just at the side wall. This increase varies between (24 to 55%).

Providing the floor with sheetpiles, the effect of the side seepage on the potential along the floor increases. For an intermediate sheetpile of relative depth S_1/L equals to 0.25 located at relative distance l/L equals to 0.33 and end sheetpile of relative depth S_2/L equals to 0.07 the potential values increase due to the effect of side seepage by (4-55%). The above parenthized ranges indicate the lower and upper values of excess pressure which correspond to the upstream and downstream parts of floor respectively.

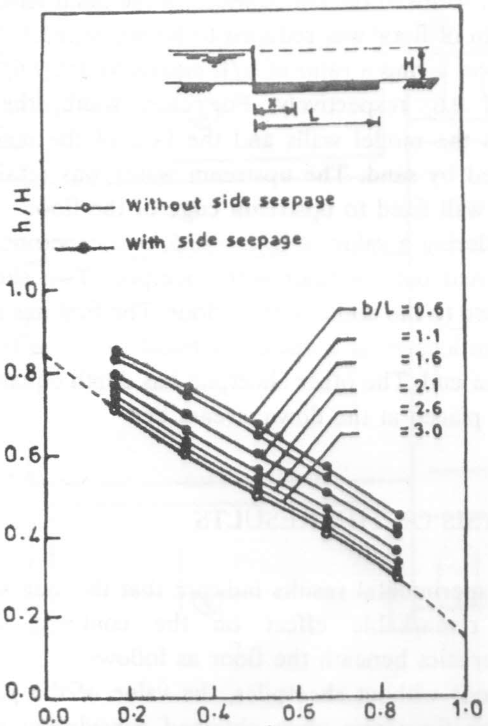

Figure 3. Relative potential along the axis of floor without sheetpiling.

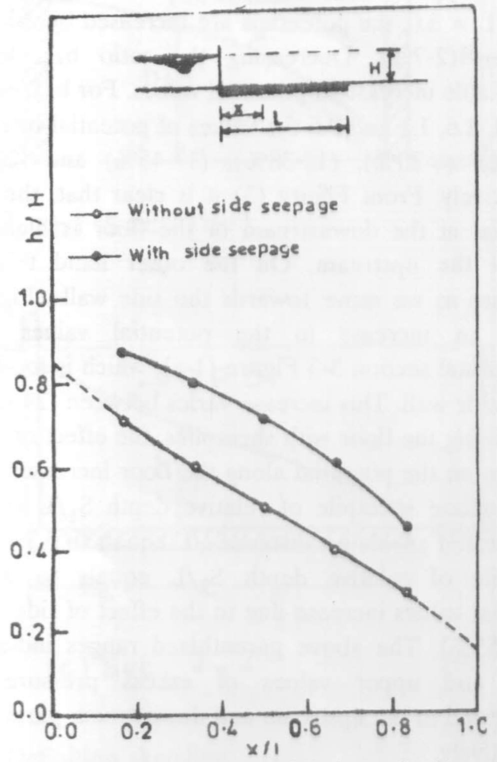

Figure 4. Relative potential along the floor length just at the side wall, sec (3-3).

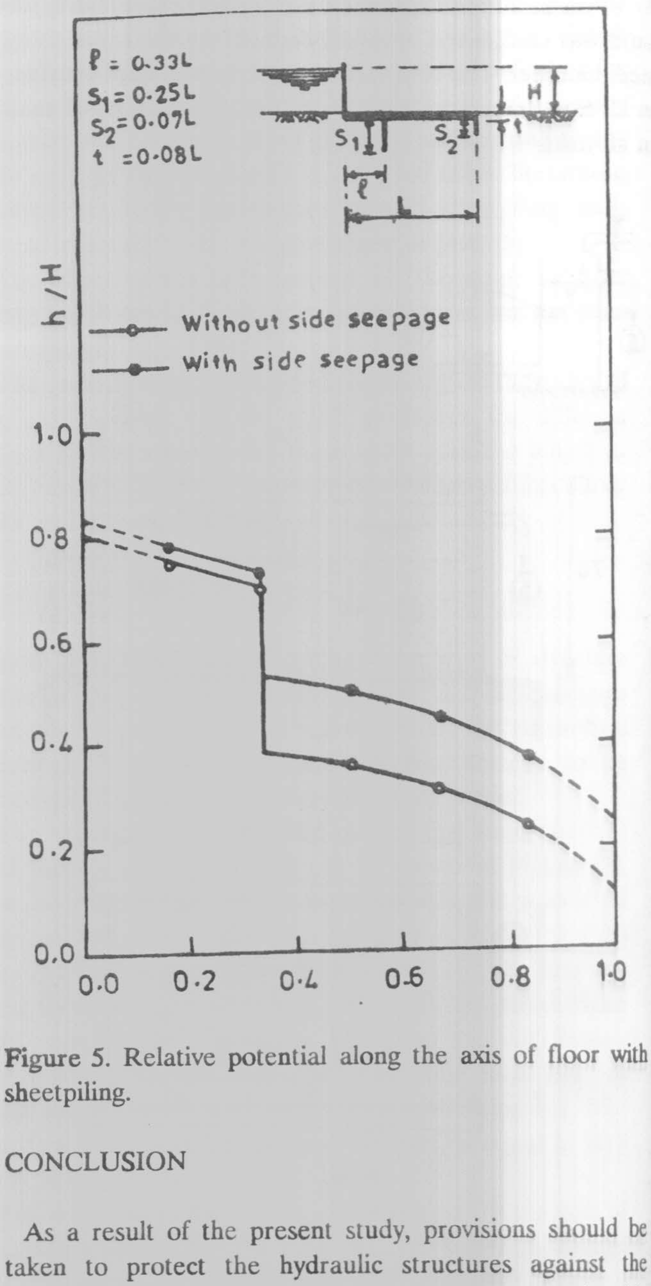

Figure 5. Relative potential along the axis of floor with sheetpiling.

CONCLUSION

As a result of the present study, provisions should be taken to protect the hydraulic structures against the excessive uplift pressure acting on the floor due to the side seepage. The following conclusions may be considered in the design of such structures :

1- The side seepage cause an increase in the uplift pressure on the floor.

2- The increase of the uplift pressure values due to side seepage increases as the relative width of the floor b/L decreases. For b/L > 2.6 the effect of side seepage is negligible.

3- The side seepage flow shows higher effect on floors with sheetpiles compared to that without sheetpiles. For b/L = 0.6, the pressures increase by 50% for floor without sheetpile. While it increases by 55% for floor with sheetpile.

4- The longitudinal sections of the floor located just at the side wall is more influenced by the side seepage compared to that at the floor axis.

REFERENCES

[1] P.G. Kicelov, *Reference Book For Hydraulic Calculations*, in Russian, Energia, pp. 235, Moscow, 1974.

[2] N.P. Rozanov, *Hydraulic Structures*, in Russian, Stroiizdat, Moscow, pp. 56-58, 1978.

[3] M.M. Grishin, *Hydraulic Structures*, Translated from Russian, Mir Publishers, Vol. 1, Moscow, pp. 95-97, 1982.

[4] P.P. Klimentov and M.V. Kononov, *Dynamics of Groundwater*, in Russian, High School, Moscow, pp. 196-201, 1985.

[5] V.P. Nedriga, *Reference Book for Design of Hydraulic Structures*, in Russian, Stroiizdat, Moscow, pp. 111-120, 1983.