# STUDY OF THE EFFECT OF IMPERVIOUS BLANKET ON SEEPAGE CHARACTERISTICS UNDER HYDRAULIC STRUCTURES

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## ABSTRACT

**The present study aims to investigate the effect of an impervious blanket length located upstream the floor of a gravity hydraulic structure on seepage discharge and potentials along the structure floor. The floor of structure has one sheetpile located at the heel point. Experiments were conducted using the Hele-Shaw model with motor's oil as viscous fluid. Design charts describing the effect of blanket on seepage quantity and potentials are given. Comparison between experiments and theoretical solution by Pavlovsky [1] showed a reasonable agreement.**

## NOTATIONS

| | |
|---|---|
| b | Distance between the two prespex sheets of the model, |
| D | Depth of sheetpile, |
| g | Gravity acceleration, |
| H | Total effective head, |
| ΔH | Loss of head along the blanket or around sheetpile, |
| h | Potential head at any point along the floor, |
| K | Hydraulic conductivity, $K=gb^2/12\ \nu$, cm/sec , |
| L | Length of floor, |
| $\ell$ | Length of impervious blanket, |
| $q_o$ | Quantity of seepage per unit width for floor without blanket |
| q | Quantity of seepage for floor with blanket, |
| Δq | Reduction in seepage quantity, $\Delta q=q_o-q$, |
| T | Thickness of permeable layer, |
| x | Distance of piezometers measured from heel point of floor, |
| ν | Kinematic viscosity of the oil, $cm^2$/sec. |

## 1. INTRODUCTION

Hydraulic structures may be subjected to unexpected increase in the effective head. One method to maintain the stability of the structure under this excess head is to remodel the structure through extending the floor length at the upstream side. This could be established by constructing an impervious horizontal blanket. Such solution considered the most practical one.

The effect of increasing floor length with impervious blanket in the upstream side on the seepage parameters along the structure floor had not been investigated l experimentally up to the author's best knowledge. However theoretical solutions by Khosla or Pavlovsky [2,3] may be used to estimate the potentials and seepage discharge. underneath the floor.

In the present study the seepage under the floor of hydraulic structure with one row of sheetpile, as shown in Figure (1) is studied.

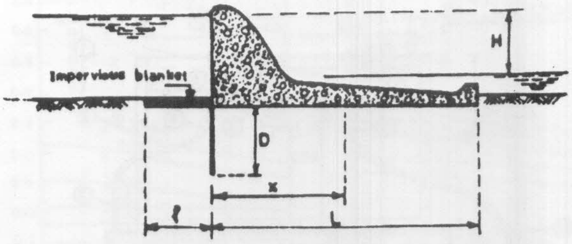

**Figure 1.** Definition sketch for seepage under gravity structure.

The sheetpile is located at the upstream end of the floor, which was found to be the most proper location in previous work [4]. Increasing the length of the blanket reduces the quantity of seepage and the uplift pressures on the under-side of the original floor. The study aims to establish a correlation between the above parameters and the length of blanket for different depths of sheetpile.

## 2. EXPERIMENTAL PROCEDURE

The seepage under the floor of gravity structures is studied experimentally using the Hele-Shaw model. In order to be free from any end effects the dimensions of the model are taken according to the recommended dimensions listed in [5] as follow;

1. The minimum length of both upstream and downstream seepage faces is chosen five times the length of floor L.
2. The permeable layer under the floor extends greater than five times the depth of sheetpile.

Accordingly, the permeable layer is assumed to be infinitely deep and the boundaries must have no influence on the values of potentials and seepage quantity. In this case the variation of potential and seepage discharge is only due to the effect of the impervious blanket length.

Figure (2) demonstrates the model arrangements, which consists of two vertical prespex sheets (1) each of 1320x800x10 mm. The two sheets are kept 1.5 mm. apart using klingarite sheet (2). The floor model (3) is formed from the same klingarite sheet. The original length of floor L is 10 cm.

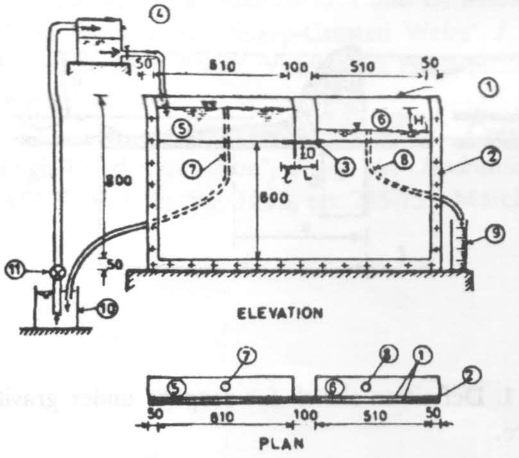

**Figure 2.** Experimemtal model.

1- Prespex sheets.
2- Klingarite sheet.
3- Floor model.
4- Elevated tank.
5- U.S. tank.
6- D.S. tank.
7- U.S. tube.
8- D.S.tube.
9- Graduared tube.
10- Collecting tank.
11- Pump.

The upstream seepage face is fed by oil from elevated tank (4). Upstream and downstream sides are provided with tanks (5) and (6) with overflow tubes (7) and (8) to maintain constant levels at the two sides. These t could be moved vertically to change the effective hea required. The overflowing oil from the downstream t is measured by graduated tube to give the quantit seepage. The overflowing oil from the tubes is collecte tank (10), from which the oil is dispatched to the eleva tank by pump (11). The flowing oil super 7500-20w 15 considered viscous fluid. Experiments are performed a constant temperature 18.5 C$^o$. Potential along the origi floor is measured by piezometers, which are made slotting the model at distance x from the heel point, whe $x/L=0.0$, 0.2, 0.4, 0.6, 0.8 and 0.95. Each slot is 2 m wide.

The experiments are performed by providing the flo with sheetpile of relative depth $D/L=0.0$, 0.25, 0.50, 0 and 1.0. For each depth the length of impervious blan $\ell$ varies as follows, $\ell/L$ = 0.0,0.25, 0.5, 0.75 and 1.0.

## 3. RESULTS AND DISCUSSION

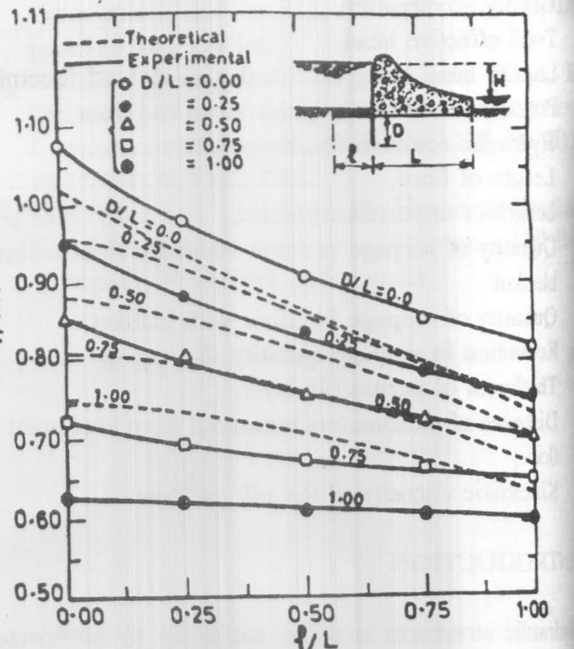

**Figure 3.** Variation of seepage discharge with lengt impervious blanket $\ell$.

### 3.1 *Effect of impervious blanket on quantity of seep*

The experimental results show remarkable effect on quantity of seepage by varying the blanket length as sh in Figure (3). It is clear that the seepage discha decreases (with decreasing rate) as the blanket leng increases. Also the sheetpile depth affects the decreasing discharge caused by the blanket, since the effect of blanket decreases while the depth of sheetpile increases. In case of flat floor (without sheetpile), $D/L = 0.0$ the seepage quantity decreases by $\approx 25\%$ for $\ell/L = 1.0$. For the same ratio of $\ell/L = 1.0$, the above value decreases to be $\approx 5\%$ when $D/L = 1.0$. Figure (3) shows that for $D/L > 0.5$ the blanket has poor effect on the change of the seepage quantity.

For $D/L = 0.0$, the relative reduction in seepage quantity $\Delta q/q_o$ is plotted versus the relative length of the blanket $\ell/L$ in Figure (4). The figure shows a nonlinear relationship. However for $\ell/L = 0.0$ the value of $\Delta q/q_o$ due to sheetpile is linearly changing with $D/L$ as demonstrated in Figure (5).

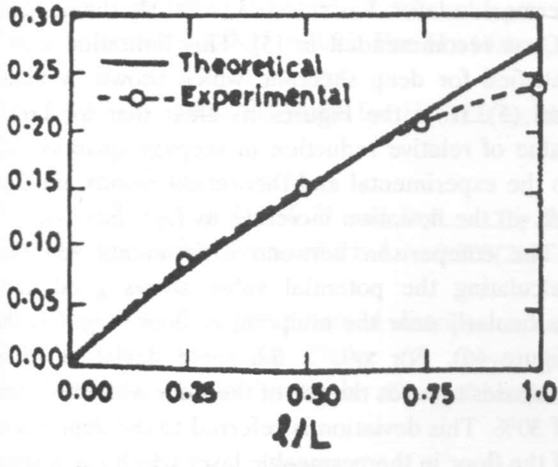

Figure 4. Effect of blanket length on the reduction of seepage discharge, when $D = 0.0$.

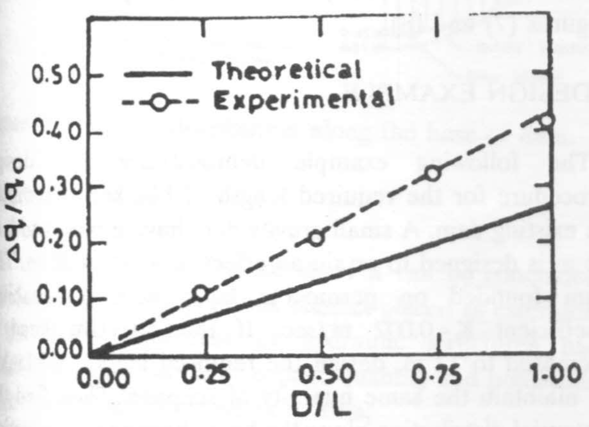

Figure 5. Effect of sheetpile depth on the reduction of seepage discharge when $\ell = 0.0$.

A comparison between Figures (4) and (5) shows that the sheetpile depth has greater effect on the seepage quantity compared to blanket's effect. While the reduction of seepage discharge equal to 25% is achieved when $\ell/L = 1.0$ and $D/L = 0$, about 40% reduction is obtained for $\ell/L = 0$ and $D/L = 1.0$.

### 3.2 *Effect of impervious blanket on potential*

The potential along the floor length is measured at positions of relative distance $x/L = 0.0$, 0.2, 0.4, 0.6, 0.8 and 0.95. For each position the relative potential $h/H$ is plotted against $\ell/L$ for different values of $D/L$ as shown in Figure (6). The figure shows a decrease in potential values upon an increase in blanket length.

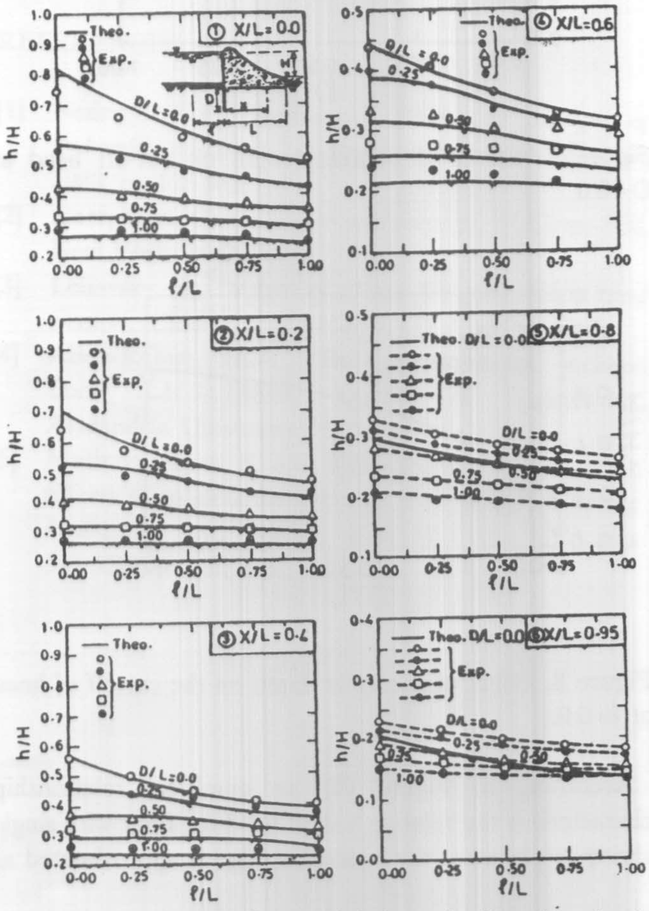

Figure 6. Variation of potential along the floor length with length of blanket $\ell$.

For each position the sheetpile depth gives a remarkable effect on the reduction of potential caused by the blanket length. For $D/L \leq 0.25$ the blanket length has notable effect on potential values. Such effect diminishes at

D/L>0.5. On the other hand the blanket length has more effect on potential at the upstream half of floor length than the downstream one.

The relative loss of potential $\Delta H/H$ caused by the blanket length or the sheetpile depth is presented in Figures (7) and (8). It is shown that the sheetpile has stronger effect than the blanket.

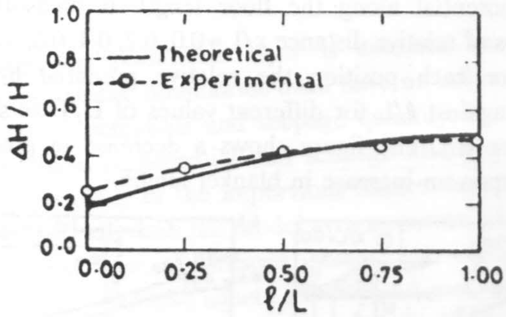

Figure 7. Effect of balnket length on cut-off head at D=0.0.

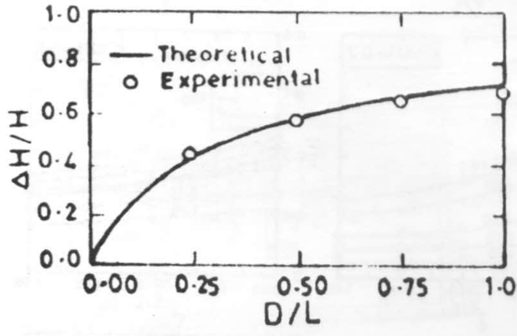

Figure 8. Effect of sheetpile depth on the cut-off of head at $\ell=0.0$.

According to Figure (8) an empirical relationship characterizes the relative loss of head for floor with single sheetpile placed at the upstream edge is approximated as

$$\Delta H/H = 0.7 + 0.171 \ln(D/L) \tag{1}$$

To obtain 100% loss of head by sheetpile, the ratio D/L should be equal to 6 in relationship (1). Since the length of floor was taken 10 cm during experiments, the sheetpile depth must be extend to 60 cm, which is the same depth taken for the permeable layer in experimental model.

### 3.3 *Comparison between experimental and the* *results*

For the same parameters involved in the experi study, the quantity of seepage and potentials unde the floor were calculated using Pavlovsky solution seepage flow under a structure on surface of infinite of porous media.

In regard to the seepage discharge, the comp shows some deviations between the experimental a theoretical values specially for deep sheetpiles as sho Figure (3). For D/L=0 the experimental values of se quantity is higher than the theoretical values. For ratio of D/L, theoretical values are higher. The maxi deviation between experimental and theoretical ranges between +10 to -20%. The lack of agreement be due to the boundary effect. However the dep permeable layer T is selected to satisfy the condition 5D as recommended in [5]. This limitation may be satisfied for deep sheetpile which shown by Figures and (5). from the Figures its clear that for D/L=0 value of relative reduction in seepage quantity accor to the experimental and theoretical results are close. $\ell/L=0$ the deviation increases as D/L increases.

The comparison between experiments and theory calculating the potential value shows good agreem particularly near the midpoint of floor length as shown Figure (6). For x/L ≥ 0.6 some deviation occurs increases towards the toe of the floor with maximum va of 30%. This deviation is referred to the depression de of the floor in the permeable layer which is not consider in the theoretical solution. However a good agreeme exists between theoretical and experimental values potential losses caused by blanket or sheetpile as shown Figures (7) and (8).

## 4.DESIGN EXAMPLE

The following example demonstrates the desig procedure for the required length of blanket to remode an existing dam. A small gravity dam having base width 2o m is designed to retain an effective head of 10 m. Th dam founded on permeable layer with permeabilit coefficient K=0.002 m/sec. If the effective head increased to 12 m, design the required length of blanke to maintain the same quantity of seepage. Then find the potential distribution along the base showing the reduction in potential values caused by blanket for the following two cases;

1. Dam without sheetpile.
2. Dam with single sheetpile 5.0 m depth.

*Solution*

According to the experimental results, the constant q/KH for dam without sheetpile is 1.075, then for H=10.0 m

$$q = 1.075\ (0.002)(10) = 0.0215\ \text{m}^3/\text{sec/m}'.$$

To maintain the above value of seepage quantity by blanket for H=12.0 m, the constant q/KH will reduce to be; $q/KH = 0.0125/12(0.002) \approx 0.9$.

Using Figure (3), for $q/KH=0.9$ and $D/L=0$ , the corresponding relative length of blanket $\ell/L=0.542$, from which $\ell = 0.542(20) = 10.8$ m.

Similarly, for dam with sheetpile of 5.0 m depth or $D/L=0.25$ the constant $q/KH \approx 0.95$. For H=10.0 m, $q = 0.95(0.002)(10) = 0.019\ \text{m}^3/\text{sec/m}'$.

To keep the above value the same for H=12.0 m, the constant

$q/KH = 0.019/12(0.002) \approx 0.79$.

From Figure (3), for $q/KH=0.79$ and $D/L=0.25$, the relative length $\ell/L=0.708$, from which $\ell = 0.708(20) = 14.2$ m.

For the above two cases, the potential distribution can be obtained using Figure (6). Figure (9) shows the reduction in potential values due to the effect of blanket.

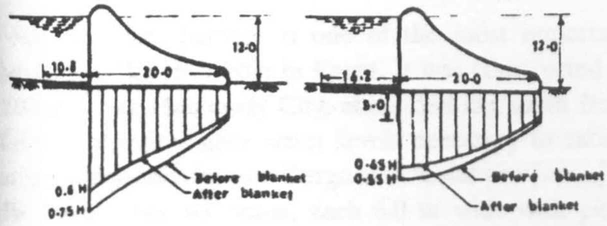

Figure 9. Potential distribution along the base of dam.

## 5. CONCLUSIONS

On the basis of the present study it can be concluded that the horizontal impervious blanket placed as extension to the floors upstream of hydraulic structures has remarkable effect on both seepage quantity and potentials which may be summarized as follows;

1. For floor without sheetpile, a blanket of length equal to one times the floor length gives 25% reduction in seepage quantity.
2. The deeper is the sheetpile, the smaller is the effect of blanket on seepage quantity and potentials.
3. The maximum depth of sheetpile at which the blanket is considered effective on seepage quantity is D=0.5L and on potential is D=0.25L respectively.
4. The potential values along the upstream half of floor length is strongly affected by the extension of blanket. This implies that the blanket has no effect on the exit gradient.

Design charts describe the effect of blanket length on the seepage characteristics are constructed as shown by Figures (3) and (6).

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