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EFFECT OF END SHEET PILE ON THE LENGTH OF FILTER DOWNSTREAM HEADING UP STRUCTURES

تأثير الستاره الطرفيه على طول المرشح خلف منشآت الحجز

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الخلاصه : فى هذا البحث تم دراسه تأثير وجود الستارة الطرفيه على الطول المناسب للمُرشح خلف منشآت الحجز الهيدروليكيه ۔ إستخدم فى هذه الدراسه طريقه العناصر المحيطيه وذلك بعد مقارنه نتائجها بنموذج آخر مستخدمين نظريه العناصر المحدوده (العنصر الثلاثى البسيط ـ العنصر الرباعى العام) هذا وقد مُثلت النتائج فى صورة غير بعديه ۔ أوضحت النتائج أن زياده عمق الستارة الطرفيه يؤدى الى زياده فى قوه التعويم أسفل المنشأ وكذا زياده فى الطول المطلوب للمُرشح خلف المنشأ كما تؤدى زياده الستارة الطرفيه الى تقليل كميه المياه المتسربه أسفل فرشه المنشأ وكذا تقليل فى الميل الهيدروليكى عند المخرج ۔ هذا وقد خلصنا الى أن الطول المناسب للمُرشح خلف المنشأ يتراوح ما بين ٧ـ٩ أمثال الضغط المسبب للتسرب۔

ABSTRACT : A study on the effect of having an end sheet pile on the proper length of the filter installed downstream heading up structures is presented in this paper. The boundary element method is used in getting the numerical results, which are non-dimensionally presented. The results show that, increasing the sheet pile depth increases the uplift pressure on the structure and the required length of the downstream filter. The proper filter length downstream the structure is found to be ranged between 7-9 times the seepage head. Seepage flow and exit gradients are decreased with increasing the sheet pile depth.

INTRODUCTION

To improve the seepage characteristics and reduce the maximum exit gradient a system of sheet piles as well as downstream graded filter were provided. The problem of confined flow through homogeneous and isotropic soil beneath a concrete dam has been solved considering the case of a dam without any filter and taking into account an infinite downstream discharge face [7,8, and 9].

A graphical solution for the above mentioned problem [3] according to Forchheimer's trail and error method and approximate solution for the problem [6], accounting for the existence of a downstream filter, are also available. Pavlovsky [9] and Muskat [7] solved, independently, the problem of a dam with single sheet pile. They also provided graphical solutions for the case of symmetrically placed pilings [5].

The case of the proper length of the downstream filter installed adjacent to a heading-up structure with a flat floor. has been studied numerically using the boundary element method (B.E.M) by [4].

In this paper the objective is to illustrate the effect of having an end sheet pile on the downstream filter length and on the characteristics of seepage considering confined seepage beneath a heading-up structure shown in Fig.(1). As a case for some designers may use. It does not mean that this case is the optimum design for a heading up work.

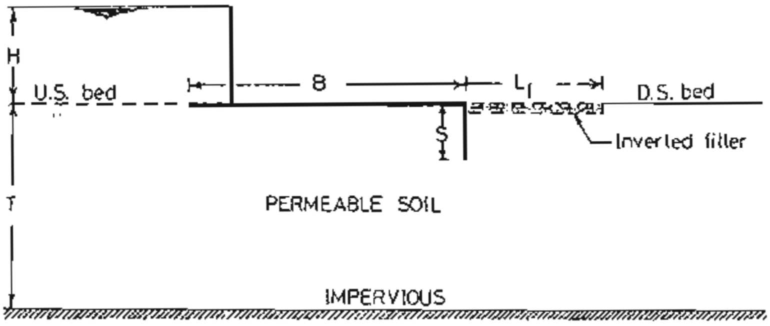


Fig.1- Layout of the problem

The boundary element method is used in performing the calculations for the problem considering $T/B = 3.$, $S/B = .1 - .5$ *and* L_f/H *up to 11.*

GOVERNING EQUATION AND BOUNDARY CONDITIONS

In two-dimensional steady flow in homogeneous isotropic soil. the governing differential equation is that of Laplace:

$$K\left(\partial^2 u / \partial x^2 + \partial^2 u / \partial y^2\right) = 0 \qquad (1)$$

in which K is the hydraulic conductivity of the soil and u is the potential head.

The boundary conditions corresponding to this problem are of two types :

a) Essential or Direchelt condition. such as $u = \bar{u}$ *on* Γ_1,

b) Natural or Numman condition. of the type $\partial u/\partial n = q$ *on* Γ_2.

The total boundary is $\Gamma = \Gamma_1 + \Gamma_2$.

APPLICATION OF THE BOUNDARY ELEMENT METHOD.

The idealization of the problem is shown in Fig. (1), in which the domain Ω *is bounded by a surface,* Γ*, whose normal is n, positive outward. Using a general, two dimensional cartesian system of coordinates:* $(x_i,\ i=1,2)$*, and for constant K, Laplace equation can be written as follows, at any point* (x_i) *in the domain:*

$$u\ (x)_{i,i} = 0 \tag{2}$$

in which $u = (p/\gamma) + z$ *, is the potential head,* (p/γ) *is the pressure head and z is the position head, measured upward from the impervious layer level.*
The corresponding components of the flow vector V_i *are given by Darcy's law as:*

$$V_i = - K\ u_{,i} \quad , \tag{3}$$

The current problem is a mixed boundary value one, with the potential head, u, or the flux, q, specified on each portion of the surface, Γ*.*

Utilizing the reciprocal integral identity corresponding to the differential equation (2), the direct boundary integral equation is written as [1,2] :

$$\alpha\ u\ (x_o) + \int_\Gamma u\ q^* d\Gamma - \int_\Gamma q\ u^* d\Gamma = 0 \tag{4}$$

in which $q^* = \partial u^* / \partial n$ *.*

$$\alpha = \omega\ /\ 2\pi \tag{5}$$

ω = *internal angle of the surface at point* (x_o)*.*
α = *1 at any point, x, in the domain* Ω*, and*
u^* = *potential generated at a field point* x_i *by a unit source applied at a surcharge point* x_j *.*

To make use of equation (4), the surface, Γ*, of the domain is discretized to (N) linear boundary elements. The values of u and q are assumed to be changed linearly on each element, then equation (4) is written at each nodal point. For all values of i=j, the integrals given by equation (4) were calculated using a 4- point Gauss quadrant rule.*

whereas for i=j the value of these integrals are given by [2] in closed form. Then equation (4) becomes:

$$(H_{ij} + \delta_{ij})\; u_j - G_{ij}\; q_i = 0 \qquad (6)$$

where δ_{ij} *is the Kronecker delta function.*

$$G_{ij} = \int_{\Gamma} u^{*}\, d\Gamma \qquad (7)$$

$$H_{ij} = \int_{\Gamma} q^{*}\, d\Gamma \qquad (6)$$

The physical situation outlined in Fig.(1) is defined as:

- *The potential u along the U/S and D/S surfaces has the values u= H + T and u=T for the case of dry downstream, respectively.*
- *The flux q normal to the impervious boundaries is equal to zero.*

Introducing these boundary conditions into equation (6), gives the following unknown boundary values:

- *The flux q along the inlet and outlet surfaces.*
- *The potential u along the impervious boundaries.*

VERIFICATION OF THE MODEL

In order to verify the boundary element model, results for the case of S/B = 0.3, T/B = 3, and L_f/H *=1., have been compared with those based on the Finite Element model using the three-noded triangle and the four node isoparametric elements as shown in the finite element discretization, Fig.(2).*

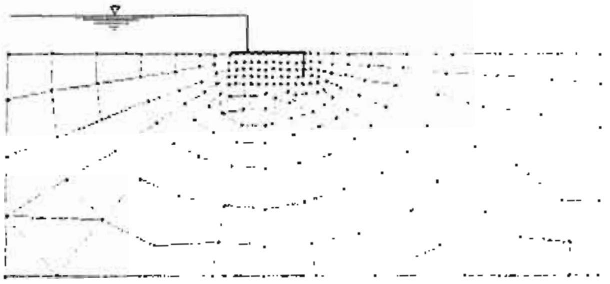


Fig.2- Finite element mesh using 192 elements with 197 nodal points.

In Fig.(3) the computed uplift pressure on the structure using the B.E. model and the F.E. technique has been illustrated to exhibit the accuracy of the present model.

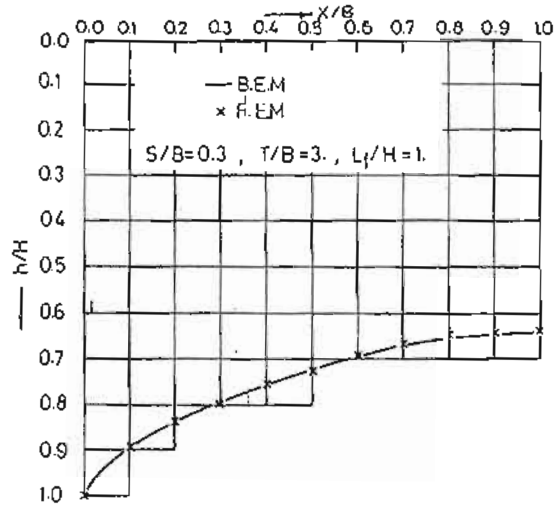


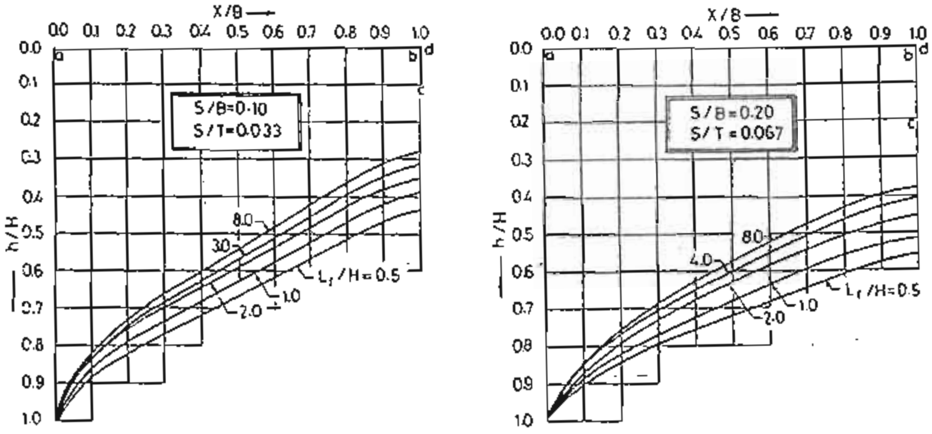
Fig.3- Comparison between the present solution and that obtained using F.E.M.

From the computed potentials for the considered cases (S/B= 0.1→ 0.4) Figs.(4a, b,c, and c) have been illustrated to show the effect of the downstream filter length on the acting uplift pressure on the structure.

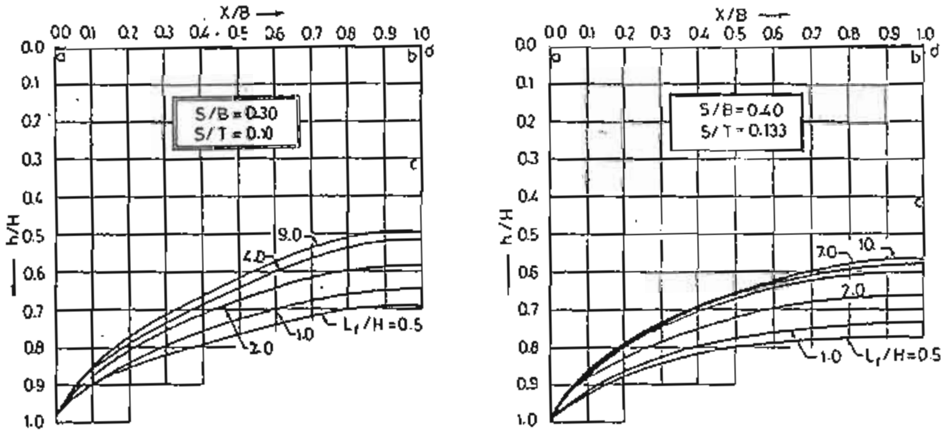
The computed uplift pressure at the end of the solid floor and just before the end sheet pile. point b in Fig.(5). has been illustrated in a percentage form of the final value that obtained when the downstream filter length has no effect on the computed pressures. These pressures have been plotted versus the relative length of the downstream filter L_f/H. From this figure it is clear that the relative length L_f/H ranged from 7 → 9 is enough to be installed D/S the structure.

Considering the relative depth of the end sheet pile with respect to the permeable soil thickness, S/T, from 0.033 to 0.167, Fig.(6) illustrates the relationship between L_f/H and h_b/H, where h_b is the uplift pressure at point b and H is the seepage head. From this figure one can *observe that the downstream filter length has no influence in the uplift pressure especially at point b for L_f/H greater than 9.*

Equipotentials for one of the computed cases considering $S/B= 0.3$, $T/B = 3$, and $L_f/H =1.$, have been illustrated as shown in Fig.(7).



a) S/B = 0.1 *b) S/B = 0.2*



c) S/B = 0.3 *d) S/B = 0.4*

Fig.4- The uplift pressure beneath the structure for different values of S/B and L_f/H

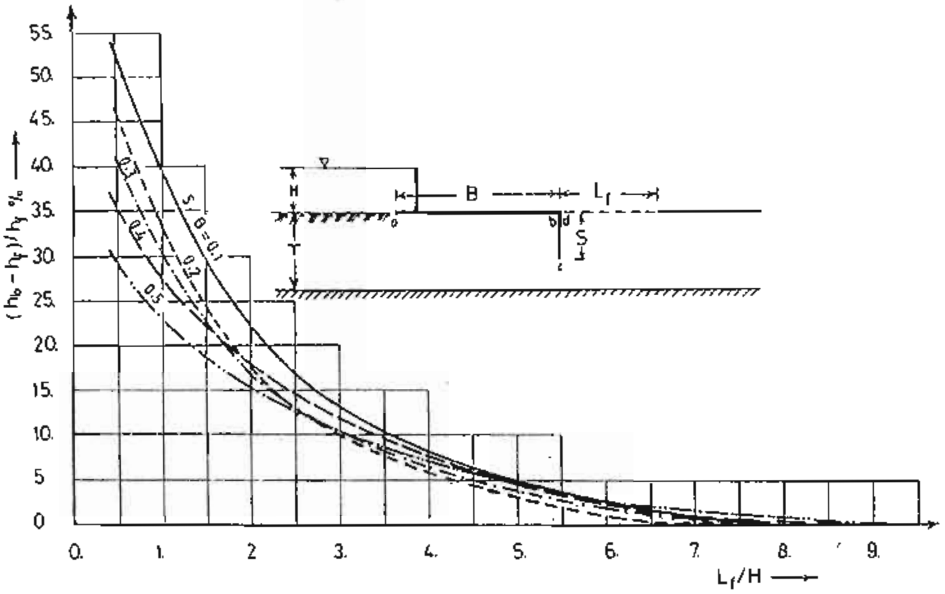


Fig.5- Variation of the relative uplift pressure at b with L_f/H for S/B from 0.1 to 0.4.

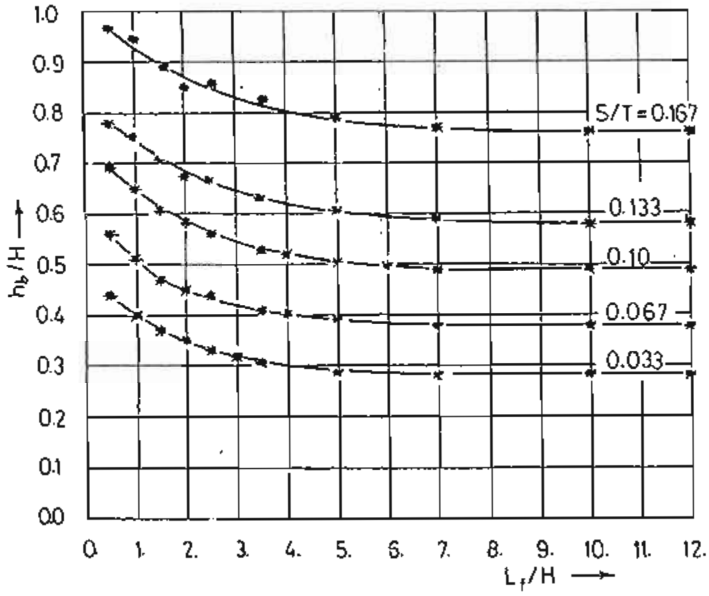


Fig.6- Variation of h_b/H with L_f/H for different values of S/T.

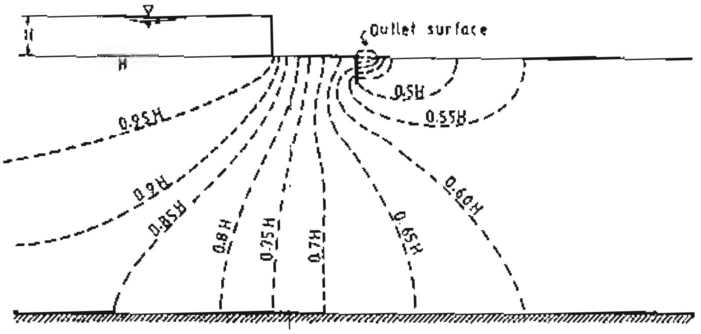


Fig.7- Equipotentials for one of the considered cases
(S/B= .3, T/B= 3. and L_f/H = .1)

To illustrate the relation between seepage flow, Q, and the downstream filter length, L_f, for different sheet pile depths, S, Fig.(8) shows the obtained results in the form of dimensionless parameters. From this figure it is clear that the seepage flow does not change if the downstream filter length is about 7→ 9 times the seepage head. Also, increasing sheet pile depth decreases the seepage flow.

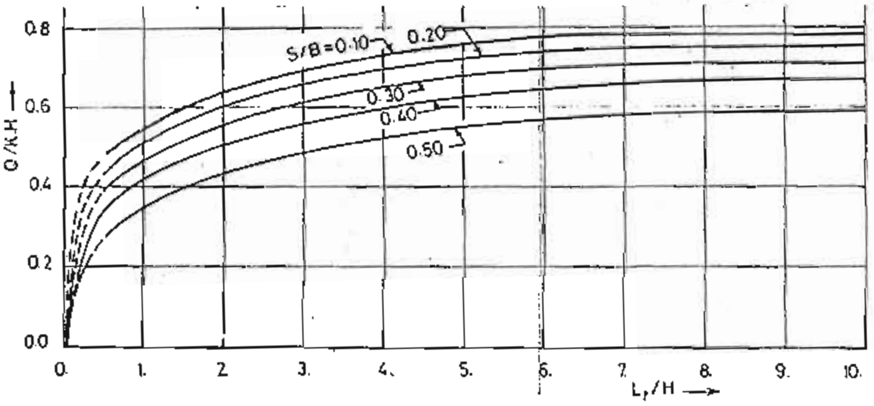


Fig.8- Variation of Q/k.H with L_f/H for different values of S/B.

Finally, the computed exit gradients for the considered cases have been illustrated with the variation of the downstream filter length as shown in Figs.(9, 10, 11, and 12). From these figures one can observe that the downstream filter length and the sheet pile depth have a greet effect on the exit gradients at the outlet surface.

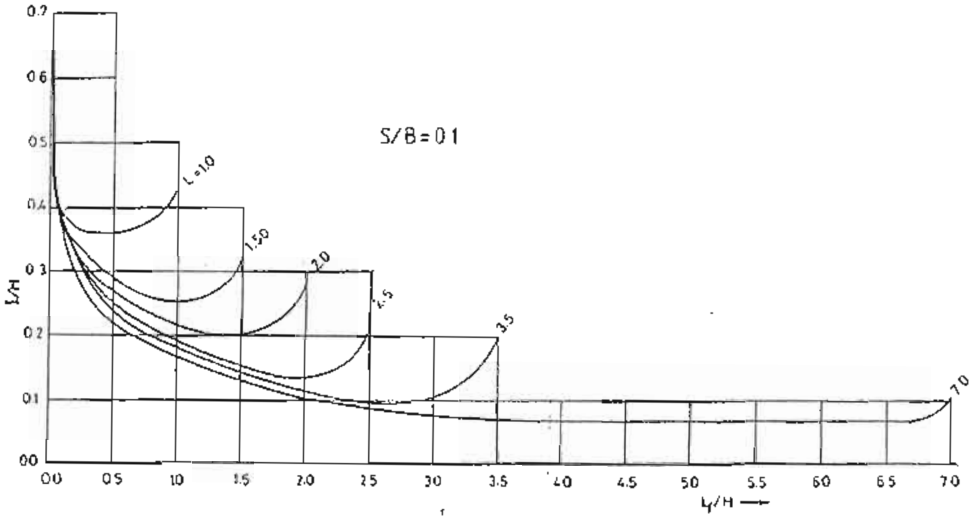


Fig.9- Variation of exit gradient with L_f/H for S/B= 0.1

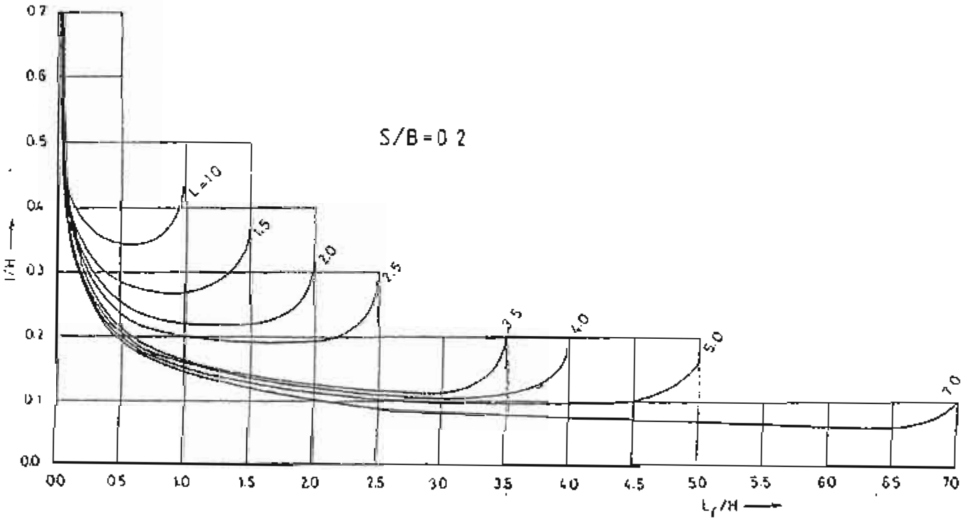


Fig.10- Variation of exit gradient with L_f/H for S/B= 0.2

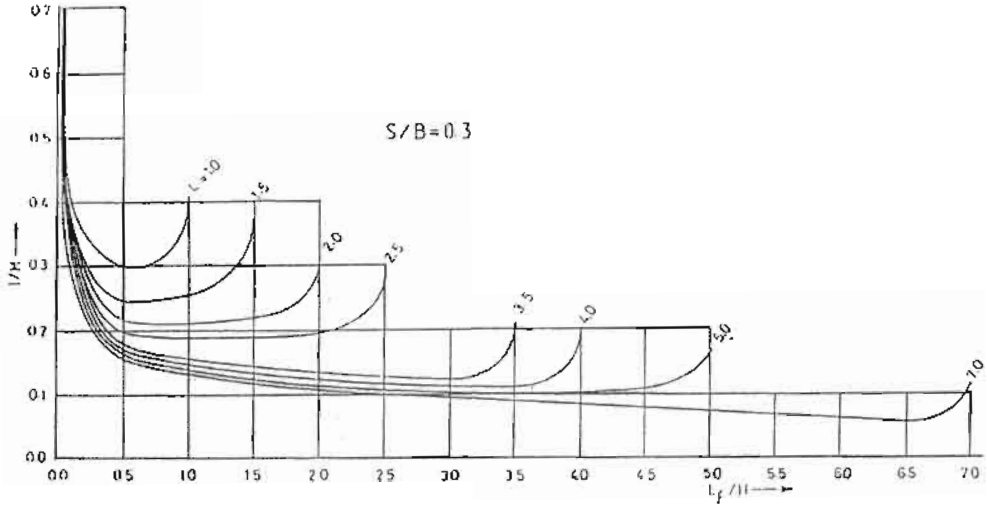


Fig.11- Variation of exit gradient with L_f/H for S/B= 0.3

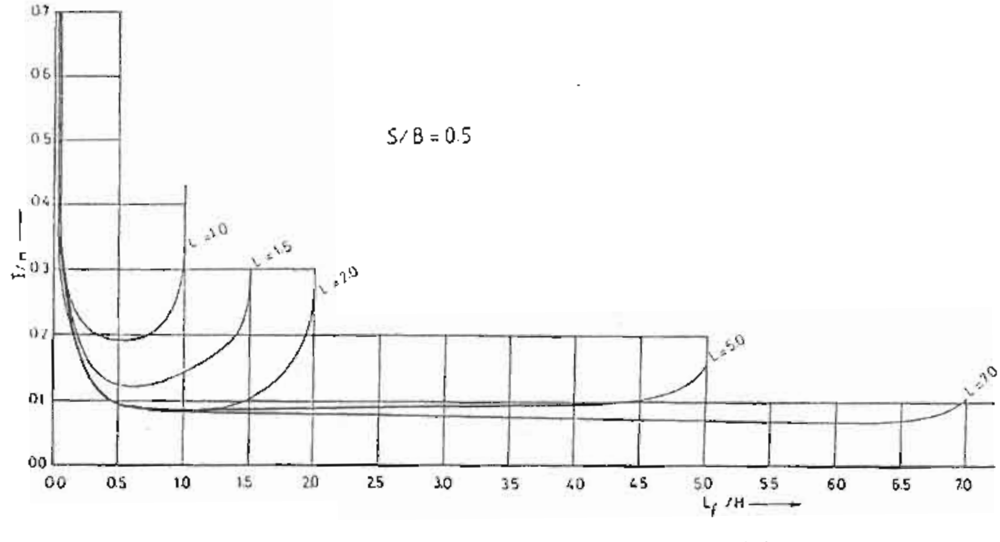


Fig.12- Variation of exit gradient with L_f/H for S/B= 0.5

CONCLUSIONS

The influence of end sheet pile on seepage characteristics underneath heading-up structures and on the proper length of downstream filter has been numerically analyzed using boundary element model. The model has been verified using finite element technique. The present study clearly indicates that:

1- Increasing the sheet pile depth increases the required downstream filter length that installed adjacent to the floor of the structure.

2- The proper length of the filter in the presents of end sheet pile is about 7→9 times the seepage head for sheet pile depth not more than half of the floor length.

3- Increasing the sheet pile depth consequently decreases the seepage flow and exit gradients at exit, and increases the uplift pressure on the structure.

4- Substantial increase in the uplift pressures on the structure may result from filter length if it is followed with an impervious boundary.

5- This case does not indicate an optimum design schame for heading-up work. it requires a larger length of filter. and the use of no D.S. sheet pilling may not require this length of filter.

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