cutoff and a horizontal filter of any dimension, located anywhere downstream of the cutoff founded on permeable soil of finite depth with the help of conformal mapping.

The result indicate that, the uplift pressure decreases considerably along the entire profile of the structure with provision of filters of even very small length. The uplift pressure decreases on the upstream side and increases on the downstream side of the filter as it is moved upstream from a downstream position. However the increase in pressure on downstream movement is very small. Therefore, it is advantageous to provide the filter to the gate line. The results indicate that the up lift pressure and exit gradient decreases with decrease in the depth of pervious strata.

REFERNCES

1) Akhilesh K., B . Singh and A. S. Chawla, "Design of Structures with Intermediate Filters", J. of the Hydraulic Division, ASCE, Vol.112, No. HY3 March - 1986, PP 206-219

2) Chawla, A. S. ," Stability of Structures with Intermediate Filters", J. of the Hydraulic Division, ASCE, Vol. 101, No. HY2, Feb. 1975, PP234-241.

3) Meleshchenko, N.T., "Computation of Graund Water Flow Under structures Fitted whith Drain Holes", Izvestiya Mauchnoisledovatebrkogo Institute Gidrotakhniki, Vol. 19, 1936.

4) Numorov, S.N., and Aravin, V. I., "Seepage Computations in Hydraulic Structures", Goostriizdet, Union of Soviet Socialist Republics, 1948.

5) Pourebraheem G.R., "An Investigation into the Effects Subsurface Drainage Upon Uplift Pressure and Exit Gradient in Hydraulic structures", Thesis Submited to the Department of Civil Engineering, University of Science and Industry for the Degree of MSc, 1987.

6) Zamarin, E.A., "The Flow of Ground Water under Hydraulic Structures" Tashkent, Union of Soviet Socialist Republics, 1931.

The steady seepage through the pervious foundation of the structure, which causes uplift, is governed by the Laplace equation:

$$-\frac{\partial^2\varnothing}{\partial x^2}+\frac{\partial^2\varnothing}{\partial y^2}+\frac{\partial^2\varnothing}{\partial z^2}=\nabla^2\varnothing=0 \qquad (1)$$

in which $\varnothing$=velocity function=-Kh; h=the head; and K=the permeability coefficient.

Without loss of generality, the head,h, along the downstream bed can be taken as o, the head measured above this, $h=H_1$, as the head in the filter and $h=H_2$ as the head in the upstream bed. Along the upstream bed, MB_1, $\varnothing=KH_2$, and on the downstream bed, B_2M, $\varnothing$=o. The foundation profile $B_1\, l_1 0 l_2 F$ forms the inner boundary of upstream flow and therefore can be taken as the stream line ψ=o, in which ψ is stream function. The foundation profile GB_2 forms the inner boundary of downstream flow and may be taken as stream line $\psi=q_1$ in which q_1= discharge per unit width, normal to the direction of flow, drained through the filter. Starting from somewhere at the upstream end the stream line $\psi=q_1$ would meet the floor GB_2 at some point J where it would divide into two stream lines, one along JG emerging at G and the other emerging at B. The potential along the floor, GB_2, would be maxmum at J. the impervious boudary MM_1 forms another stream line $\psi=q_2$ in which q_2=total discharge seeping blow the foundation. The complex potential is represeted by $\omega=\varnothing+i\psi$ The layout of various boundaries in the ω–plane is shown in Fig(1). The region of complex seepage potential is the area in ω- plane between the two verticals B_1M ($\varnothing$=- KH_2) and B_2M_1 ($\varnothing$=0) and bouded on upper side by lines B_1F (ψ=0), FG ($\varnothing$=-KH_1), and GJC_2B_2($\psi=q_1$), and on the lower side by MM_1($\psi=q_2$).

To obtain the solution, both the profile of the structure in the Z-plane and the complex seepage potential in the ω-plane have been trasformed into the lower half of the same semi-infinite t-plane, using the socalled Schwartz-Christoffel transformation. The following relations are thus obtained:

$$Z=f(t) \quad \text{or} \quad \frac{dz}{dt}=M\frac{(t-\lambda)\,/\,(t-\beta_2)(t-\beta_2)}{(1-t)\sqrt{t(t-\delta)(t-\sigma)(t-\mu)}} \qquad (2)$$

$$\omega=F(t) \quad \text{or} \quad \frac{d\omega}{dt}=N_c\frac{(t-a_j)}{\sqrt{t(t-a_F)(t-a_G)(\ \ -t)(1-t)}} \qquad (3)$$

Combining equations 2 and 3 leads to:

$$Z=f(t)=fF^{-1}(\omega) \qquad (4)$$

$$\omega=F(t)=Ff^{-1}(z) \qquad (5)$$

These equations have been integrated in various portion of the seepage boundaries, leading to several integral equations. The solution of these latter equations should make it possible to determine the value of transformation parameters. But as these equations are not explicit in transformation parameters, direct solution of the equations is not convenient. Therefore, an appropriate approach should be adabted. Thess equations can, for instance, be solved for physical dimensions l/l',b/l' T/l',l'/d and f/l' for assumed values of δ,σ,μ and t. Furthermore, kowning the values of a_F, a_G, a_J and u, the uplift pressure can be determined at any point below the floor by substituting the corresponding value of t in the appropriate equations.

In addition to uplift pressure, it is also important to know the hydraulic gradient at the downstream end of the apron, ie, at point B_2.

Gradient I at any point is given by I=dh/ds in which, h= the head at any point under consideration and s= distance measured along the stream line passing that point. But h= -$\varnothing$/K, therefore

$$I=\frac{1}{K}\frac{d\varnothing}{dt}\frac{dt}{dz}\frac{dz}{ds} \qquad (6)$$

Knowing that dz/ds=i and that along the floor and cutoff, ψ= constant.

$$\frac{d\varnothing}{dt}=\frac{d\omega}{dt} \qquad (7)$$

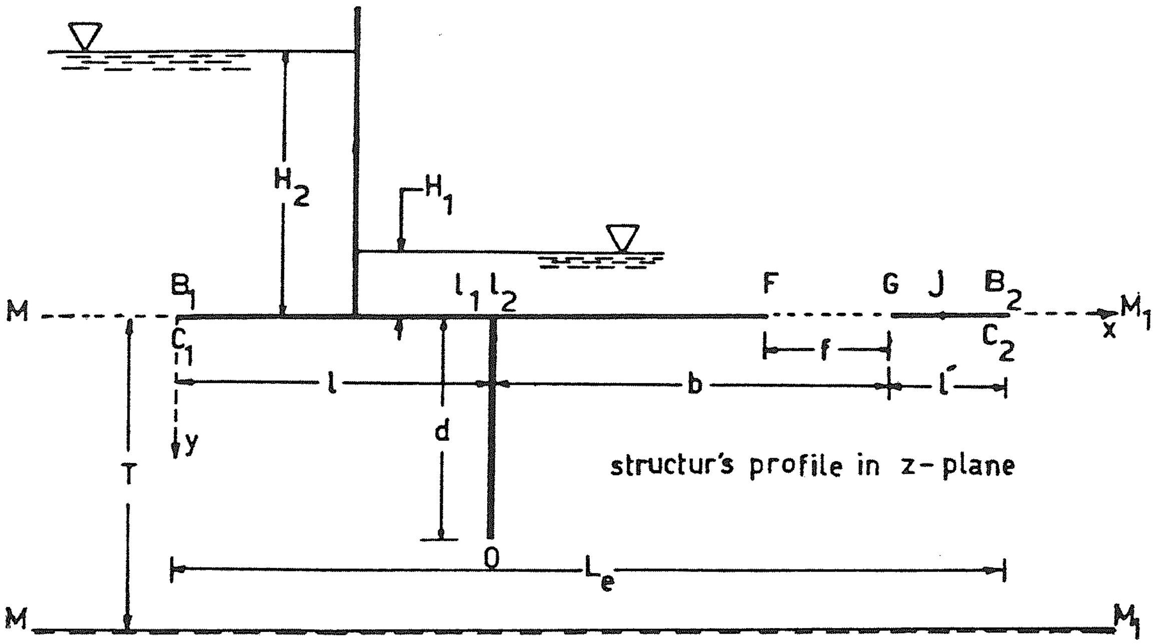
by applying a similar procedure described above, exit gradient can be expressed in terms of cutoff depth d_2 .

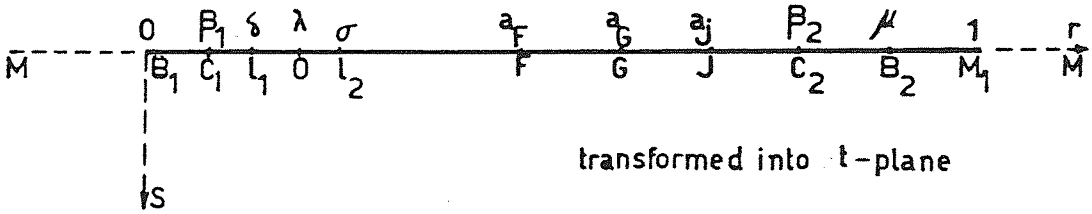
3-RESULTS

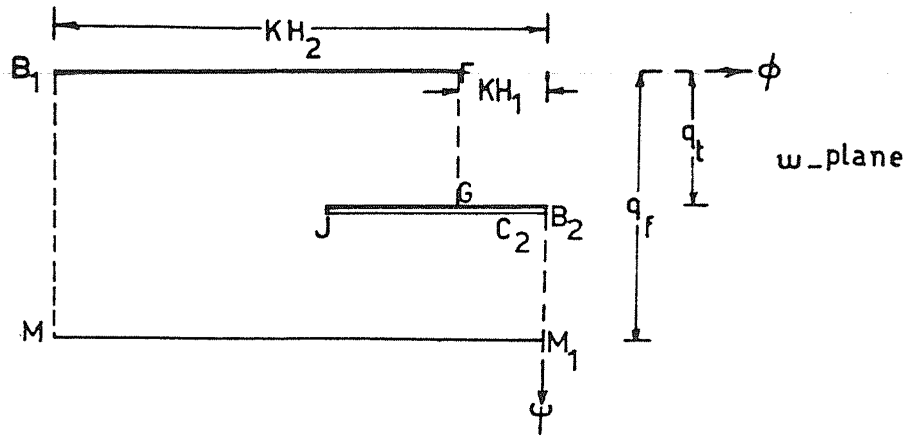
The derived equations have been used for computation of the uplift pressure and the exit gradient. These calculations involved the evaluation of many integral equations, which were computed on a digital computer by numerical methods. To facilitate the use of various equations for finding out the uplift pressure and exit gradient, the values of uplift pressure at key points and of exit gradients have been computed for diferent combinations of floor length, depth of cutoff, and depth of soil strata and were plotted in the form of curves. The result may be used for practical designs.

4-CONCLUSIONS

An exact solution has been obtained for the problem of two - dimensional seepage flow below a hydraulic structure having a flat floor and a single


H2
H1
B1
l1 l2
F
G J B2
M
M1
C1
C2
x
l
b
f
l'
y
d
T
structur's profile in z-plane
O
Le
M
M1


0 β1 δ λ σ aF aG aj β2 μ 1 r
M B1 C1 L1 O L2 F G J C2 B2 M1 M
transformed into t-plane
S


KH2
B1
F
KH1
ϕ
qt
ω_plane
G
J
C2
B2
qf
M
M1
ψ

Analysis of The Effects of Filters Under Hydraulic Stractures & Dams

Habib Bayat

Ph. D. Lecturer In Hydraulic Structures

Civil Eng. Dept. Amirkabir Univ.

Abstract:

There has been no solution available to determine the effect of plane drainage located under the hydraulic structures. In the problem under cosideration, a structure with upstream and downstream aprons and only a single line of cutoff founded on a permeable soil of finite depth is assumed. In this investigation an exact solution has been obtained using complex numbers, conformal mapping, and Schwartz-Christofell transformation. Equations for uplift pressure below the floor and for exit gradient are given. These equations involve sophesticated integrals which were evaluated at some key points only by numerical methods using a digital computer. The results indicate that, the uplift pressure is reduced considerably along the structure's entire profile with the provision of filters even of small lengths. Furthermore, uplift pressre in general, decreases along downstream side and increases along upstream side, as the filter moved from upstream to downstream. The exit gradient decreases with increasing the upstream and downstream aprons or the depth of the cutoff.

1-INTRODUCTION

The stability of hydraulic structures founded on permeable soils has to be insured against uplift pressure and piping. Intermediate filters or drains can be provided below hydraulic structures founded on permeable soils to reduce uplift pressure resulting in appreciable savings.

Many attempts (2,3,4,5) have been made to investigate the effect of drainage holes or plane drainage located somewhere between the two cutoffs under a flat apron founded on permeable soils of infinite or finite depths. But until now, no solution was available to determine the effect of a plain drainage located anywhere downstream of a single cutoff under a flat floor founded on permeable soil of finite depth. In this paper, a solution has been introduced based on conformal mapping for seepage below a flat floor with a single row of cutoff and a sheet type fiter located anywhere downstream of a cutoff, on a permeable soil of finite depth.

2-METHOD OF SOLUTION

Consider an impervious floor B_1B_2 of length L_e founded on a homogeneous permoable soil of depth T. The floor has a cutoff I_2O of depth d and is drained by a filter FG of length f at a distance b from the cutoff. The permeable soil of depth T covers an impervious strata MM_1. The profile is represented in the Z-plane as shown in Fig (1).