Short Communications

Minimum Length of Horizontal Underdrain in Homogeneous Earthdams

By

N. Babu Shankar*

Introduction

Internal drainage provisions are made in homogeneous earth dams resting on impervious surfaces to avoid the emergence of line of seepage on downstream slope and consequent erosion or piping of the embankment material. Horizontal underdrains, which attract the line of seepage to impinge on them are often provided in earthdams. From Kozeny's solution (Kozeny, 1931) it is possible to predict the parabolic shape of seepage line and to estimate the rate of discharge through the dam having certain given length of horizontal underdrain.

However, the design problem will be to predict the minimum length of horizontal underdrain which ensures a desired thickness of dry zone in the downstream portion of the earthdam. Harr (1962) has given a trial method of graphical construction for the above problem. In this paper, the author presents not only simple formulae to calculate the minimum length of horizontal underdrain but also an elegant graphical method.

Analysis

A typical cross section of a homogeneous earthdam retaining a depth of water of h on its upstream side, with a downstream slope of α° (with horizontal and resting on an impervious horizontal surface AB is shown in Figure 1. If a trial length of F_iB is provided for the horizontal underdrain, the corresponding line of seepage will be a parabola $ET_iG_iV_i$ passing through the corrected entry point E (see casagrande, 1940) and the vertex V_i with point F_i as the focus. The vertical distance F_iG_i represents the focal distance (latus rectum). If a line parallel to downstream slope is drawn such that it is tengential to the above parabola at point T_i, then it can be shown that the angle $T_iF_i\,A$ will be 2α. If the horizontal line T_iL_i is drawn perpendicular to the vertical line F_iG_i then the length $F_iL_i=(F_iG_i)$ $\cot\alpha$. Of course the length F_iG_i itself is obtained as $\sqrt{(OF_i^2 + OE^2)}$ $-OF_i$ (see Harr, 1962) where point O is the foot of the perpendicular from point E onto line AB.

---

* Asst Professor, Civil Engineering Department Regional Engineering College. Warangal-506 004 AP INDIA.

This paper was received in April, 1979 and is open for discussion till the end of September, 1980.

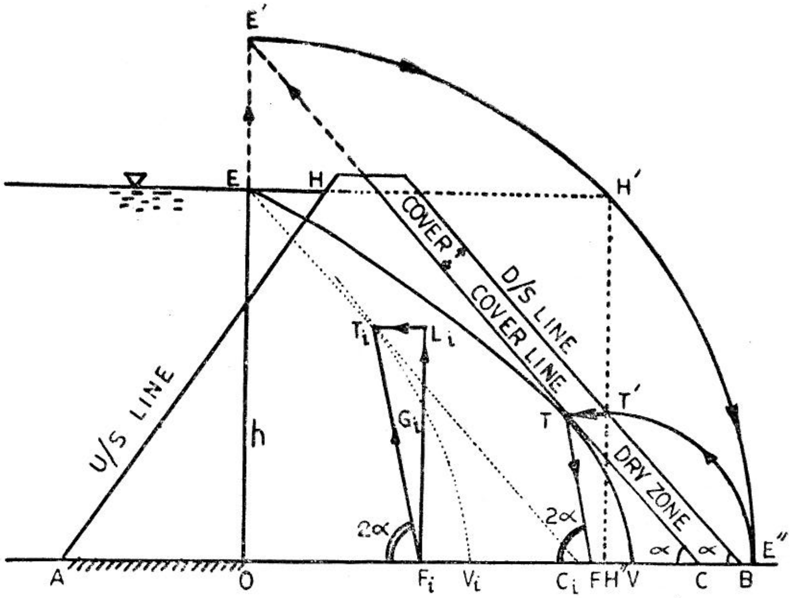

FIGURE 1. Homogeneous embankment resting on impervious surface.

Harr's Graphical Meihod

Harr (1962) suggests the following graphical method of determining the minimum length (*FB*) of the horizontal underdrain. For a given trial length of undertaken F_iB, the length F_iL_i is calculated and hence points F_i and L_i are obtained. The trial point of tangency T_i is determined from the intersection of horizontal line drawn to left from Point L_i and an inclined line from F_i drawn to the left at an inclination of 2α. Locus of T_i is drawn taking various trial values of points F_i (and hence underdrains of different tengths) and the point of intersection of the Locus of T_i with the cover line (*CT* drawn parallel to the downstream slope) yields the critical point of tangency *T*. The focus *F* of the critical parabola (line of seepage) is obtained by drawing a line *TF* from *T* at an inclination of 2α.

Analitical Method

The graphical method suggested above indicates that the critical parabola is that trial parabola which is tangential to the cover line *CT*. Let *O* be the origin and lines *OB* and *OE* be taken as the *X* and *Y* axes. Let the abscissae of points *F* (focus), *V* (vertex) and *C* be (X_i-a), X_i and X_o respectively. The equation of the straight line *CT* will be $y=m\,(X_I-X))$ where $m=\tan\alpha$. Equation of the parabola passing through points *E* (with ordinate of *h*) and *V* will be $y^2=h^2 \mid 4ax$ where $a=FV+$half the latus rectum and $x_1=h^2\ 4a$. Since point *T* will be common to this parabola and the cover line *CT*, it can be proved that

$$a=\frac{m}{2}\left[mx_o-\sqrt{(mx_o)^2-h^2}\right] \qquad \ldots(1)$$

The minimum length of underdrain is given by

$$FB = FV + VC + CC$$
$$= a + (x_0 - x_1) + (OB - x_0)$$
$$= OB + a - x_1$$
$$= OB - \frac{h^2 - 4a^2}{4a} \quad \ldots(2)$$

Thus equations (1) and (2) help in calculating the desired length of underdrain.

Alternative Graphical Method

The ordinate of point T (*i.e.* perpendicular distance of T from AB) can be proved to be equal to $2a/m$. Hence formula (1) above suggests the following graphical procedure to determine the point T, which is more elegant and straight forward than Harr's (1962) graphical method.

Extend the cover line CT to meet the vertical line OE extended in point E'. With point O as centre and QE' as radius strike are cirular arc E' H' E'' to meet the EH extension in H′ and OB in E''. From H' drop a perpendicular $H'H''$ to AB. Take H'' as centre and $H''E''$ as radius and draw another circular arc $E''T'$ to meet the vertical line $H''H'$ in T' From T' draw a horizontal line to meet the cover line in T. Of course the focus of the critical parabola is obtained from T by drawing a line TF at an inclination of 2α. Length EB gives the desired minimum length of horizontal underdrain.

Example

For a homogeneous earth dam (resting on an impervious base) and having the following particulars:

Height of the dam	=12m
Height of water retained	=10m
Topwidth of dam	=5m
Upstream slope	=1 : 3
Downstream slope	=1 : 2
Cover thickness	=1m

the minimum length of horizontal under-drain by all the above three methods works out to be 5.6m, However the author's analytical method is the simplest and quickest and Harr's graphical method takes the maximum time and labour.

Conclusions

Formulae (1) and (2) given in the paper enable one to calculate the minimum length of horizontal underdrain in a homogeneous earthdam (with a clear cover of specificd thickness on the downstream) resting on an impervious surface. Alternatively a graphical method is suggested by the author which is less cumbersome and more direct than the trial graphical method due to Harr (1962).

References

CASAGRANDE, A. (1940). "Seepage through Dams" in Contributions to Soli Mechanics 1925—1940", *Boston Society of Civil Engineers*, Boston.

HARR, M.E,, (1962). "Groundwater [and Seepage" *McGraw-Hill Book Co.*, pp 67-69.

KOZENY, J., (1931)". Grundwasserbewegung bei freiem Spiegel, Fluss und Kanal Versickerung" *Wasser kraft und Wasserwirtschaft* No. 3.