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# Dynamic Earth Pressure Distribution Behind Retaining Walls

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**SYNOPSIS:** The point of application of dynamic active thrust and its distribution are computed using the method of slices and criterion of maximization of overturning moment of the active thrust. The computations show that point of application of the dynamic thrust is significantly influenced by such factors as wall friction and acceleration coefficients. Horizontal accelerations coupled with positive vertical accelerations (acting downwards) have the effect of moving the point of application closer to the wall base. The combination of horizontal acceleration with negative vertical acceleration produces exactly the reverse effect and generates more overturning moments even though the magnitude of corresponding active thrust is less. The resulting earth pressure distribution shows a nonlinear trend.

## INTRODUCTION

The point of application of active thrust ( $P_{ae}$ ) and its distribution under dynamic conditions has been the topic of interest of research workers for quite some time. Notable among them are Basavanna (1970), Seed and Whitman (1970), and Joshi and Panigrahy (1985), who attempted to make predictions on the basis of certain simplifying assumptions.

The author used method of slices for predicting the point of application and distribution of the dynamic active thrust, in which, the analysis was made both statically determinate and unique by introducing the criterion of maximization of overturning moment of the active thrust. The details of these computations are presented and discussed in this paper.

## METHOD OF ANALYSIS

A vertical wall (height  $H = 10\text{m}$ ) with horizontal cohesionless backfill material (angle of internal friction,  $\phi = 30^\circ$ , unit weight,  $\gamma = 18\text{KN/m}^3$ ) is considered in the analysis. Plane failure surface as per the Mononobe-Okabe analysis (1929, 1926) is assumed as shown in Fig. 1 and the failure wedge is divided into a number (50) of vertical slices of equal width. On a typical slice  $r$ , the forces acting are its own weight ( $W_r$ ) dynamic forces  $K_h W_r$  and  $K_v W_r$  in horizontal and vertical directions ( $K_h$  and  $K_v$  are corresponding acceleration coefficients), interslice forces  $F_{rr}$  and  $F_{rl}$  and soil reaction  $R_r$  at its base. The analysis of forces is indeterminate because the directions of interslice forces ( $\theta_{rr}$  and  $\theta_{rl}$ ) are unknown.

On the  $n$ th slice near the face of wall (Fig. 1), one of the interslice forces is  $P_{ae}$ , acting on its left side with known direction  $\delta$  where  $\delta$  is the angle of wall friction. However the direction of other interslice force on its right side is unknown. Similarly for the first slice of

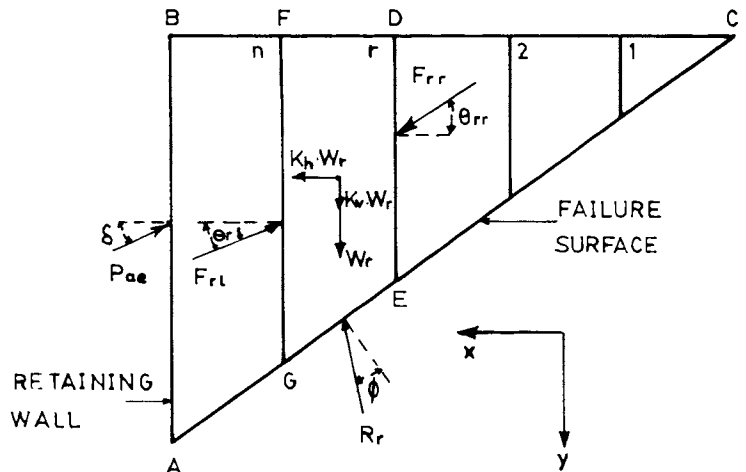


Fig. 1 Forces on a Typical Slice

triangular shape, the direction of interslice force on its left side is unknown and on its right side, for any vertical plane passing through C, the direction of interslice force would be horizontal, since point C being a part of undisturbed semiinfinite medium. Thus the directions of interslice forces vary from 0 to  $\delta$ , but the nature of variation being unknown. This may be expressed by the following relation.

$$\theta_{rl} = \left( \frac{CF}{CB} \right)^p \cdot \delta \quad (1)$$

Where :  $\theta_{rl}$  = inclination of interslice force on  $r$ th slice

CF, CB = distances as shown in Fig. 1.

The parameter  $p$  in Eq. 1 is unknown and by giving different values to  $p$ , different directions of interslice forces and hence different points of application of  $P_{ae}$  are obtained, thus making the analysis determinate but nonunique.

However the computations show that with increasing value of  $p$ , the height of point of application of  $P_{ae}$  from the base increases, in turn increasing its overturning moment and it reaches its maximum value when the directions of all interslice forces (except  $P_{ae}$ ) become horizontal as seen from Eq. 1. This situation gives maximum possible value of overturning moment of  $P_{ae}$  and also makes the analysis unique. Since overturning moment is one of the principal parameters in the design of retaining walls, it would be quite appropriate if its maximum possible value is considered in the analysis.

On the basis of above criterion, a parametric study was carried out and the results are discussed below.

#### DISCUSSION

The ratio of height of point of application of  $P_{ae}$  ( $h$ ) to the height of the wall is designated

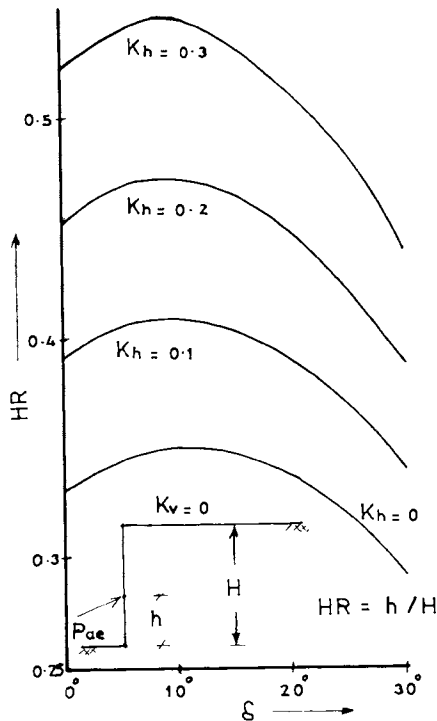


Fig.2 Variation of HR with  $K_h$  and  $\delta$

as HR and in Fig.2, the influence of  $\delta$  and  $K_h$  (with  $K_v = 0$ ) on HR is shown. It is seen that for any specified value of wall friction angle, the point of application of  $P_{ae}$  moves away from wall base with increasing  $K_h$ . For specified values of  $K_h$  and  $K_v$ , HR initially increases with increasing wall friction angle, attaining a peak and later showing a decreasing trend. Similar behaviour is indicated with other values of  $K_v$  (vertically downward positive) as shown in Fig.3

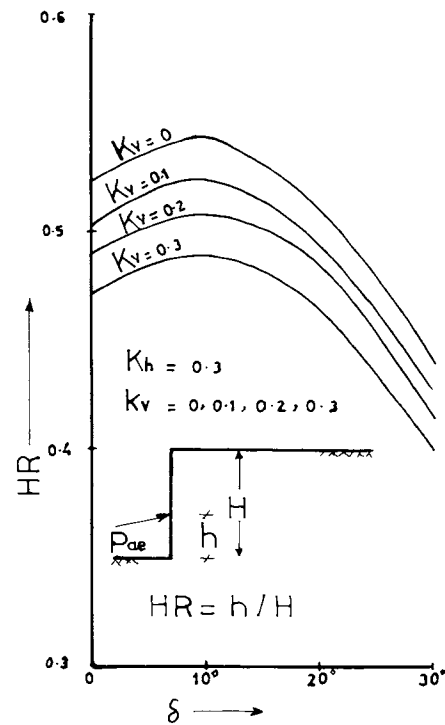


Fig. 3 Variation of HR with  $+K_v$  and  $\delta$

and Fig.4.

Fig. 3 and Fig. 4 also show the influence of positive and negative values of  $K_v$  on HR. It is interesting to note that for a specified value of  $K_h$ , with increasing positive value of  $K_v$ , the point of application of  $P_{ae}$  moves closer to the wall base; whereas with increasing negative values of  $K_v$  (-0.1 to -0.3), exactly reverse effect is obtained. Thus the computations indicate that the combination of increasing horizontal and negative vertical accelerations is more effective in generating higher overturning moments even though the magnitude of the corresponding active thrust is less as compared to the combination of horizontal accelerations and positive vertical accelerations.

In Fig. 5, the results obtained by the author are with those obtained by the method proposed by Seed and Whitman (1970), for the case of a smooth wall with  $K_v=0$ . It is seen that the HR values as computed by the author are more, thus generating more overturning moments, with a marked divergence at higher values of  $K_h$ .

Finally, the distribution of earth pressure is shown in Fig. 6 for the case  $K_v = \delta = 0$ , on which, pressure  $p_x$  along the retaining wall is expressed in dimensionless form  $(p_x/\gamma H)$ . Nonlinear trends in the distribution with increasing values of  $K_h$  are clearly noticeable in the figure.

#### CONCLUSIONS

On the basis of above computations, the following conclusions are drawn.

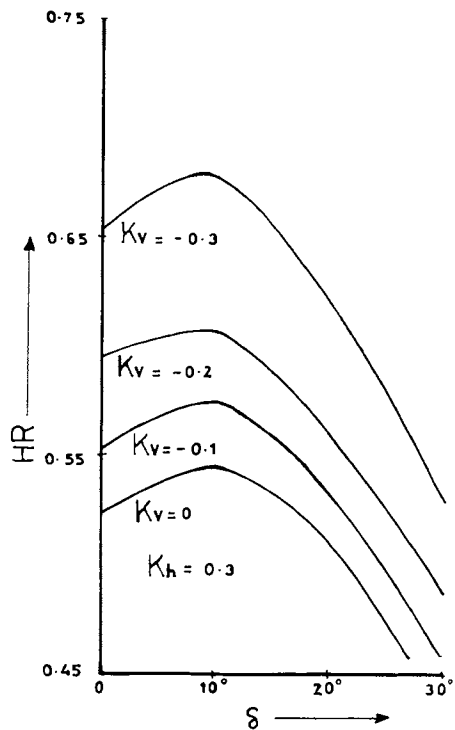


Fig. 4 Variation of HR with  $-K_v$  and  $\delta$

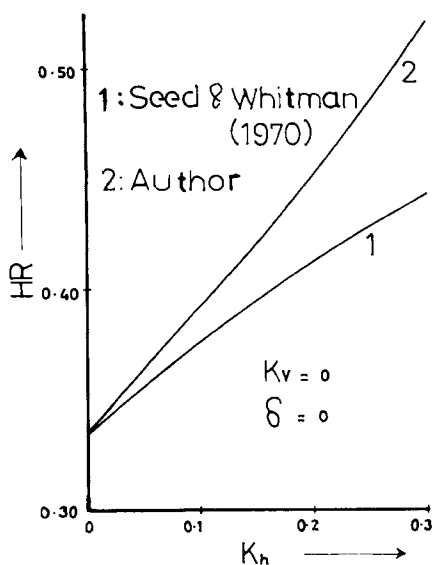


Fig. 5 Comparison of Author's and Seed and Whitman's results

1. For the backfill material of specified properties, the point of application of dynamic active thrust is significantly influenced by such factors as angle of wall friction and acceleration coefficients.
2. The combination of horizontal acceleration and negative vertical acceleration (acting upward) generates more overturning moments.
3. The resulting distribution of earth pressure is nonlinear.

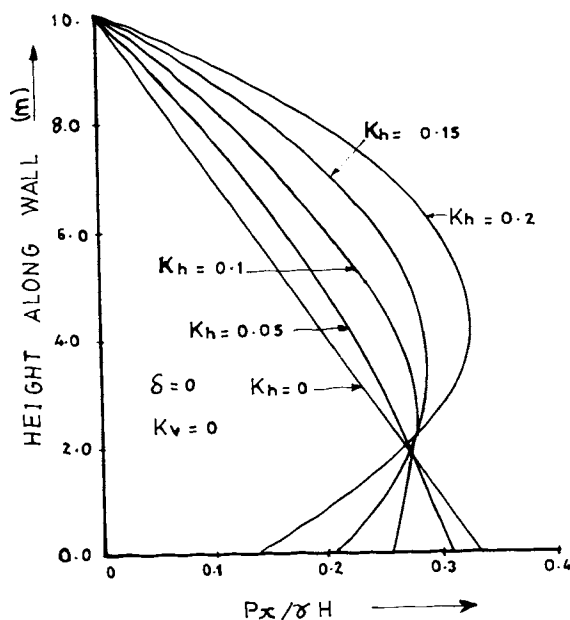


Fig. 6 Effect of  $K_h$  on Earth Pressure Distribution.

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