Active Earth Pressure on Cohesion-less Soil: Theoretical and Graphical Considerations

Arunava Thakur*1, Bikash Chandra Chattopadhyay*2

#1 *M.Tech student, Civil Engineering Department, Meghnad Saha Institute of Technology*

#2 *Professor of Civil Engineering Department, Meghnad Saha Institute of Technology*

Kolkata, India

Abstract—*Retaining structures are designed and constructed to resist lateral pressure of backfill material, generally soil, when there is a desired change in ground elevation that exceeds the angle of repose or to retain the backfill. The retained backfill material exerts pressure on the structure which when exceeds leads to structural failure. Thus, design considerations are of extreme importance and all factors that influence the magnitude of earth pressure must be thoroughly examined. The present study deals with the evaluation of active earth pressure for cohesion-less soil under different boundary conditions, dealt generally in practice. Various combinations of soil parameters like φ, α, β, height of retaining structures (H) are studied within practical ranges to evaluate their impact on active earth pressure. The magnitudes of pressure under various cases are analyzed graphically using Culmann's graphical solution and compared with those obtained using Elastic Theory which denotes the decrease in active earth pressure with the increase in load distance (0.3H, 0.5H, 0.7H) from the face of the wall*

Keywords —*Active earth pressure, Elastic Theory, graphical solution, cohesion-less soil.*

I. INTRODUCTION

Earth pressure on retaining walls plays a crucial role in the design considerations of wall. Design of these structures requires estimation of magnitude and line of action of lateral earth pressure. Retaining walls are often used to solve a variety of grade differential problems associated with these improvements. Whenever differential levels are to be maintained either with the help of retaining walls or by excavation in the ground, sheet piling situations arise in many cases. To safeguard the stability, retaining walls are constructed to accommodate the already existing structure or pre-installed loading line in case of forming new railway tracks. Several methods for determination of active earth pressure had been suggested by previous researchers among which Coulomb's (1776)[4] and Rankine's (1857) theory stood the test of time.

In a study carried out by Das (2010)[2], the stress at any depth z on a retaining structure caused by a line load of intensity q/unit length was given as

$$\sigma = \frac{2q}{\pi H}\,\frac{a^2 b}{(a^2+b^2)^2}\,\frac{2q}{\pi H}\,\frac{a^2 b}{(a^2+b^2)^2}$$

Salman et al. (2010)[1] estimated the earth pressure distribution generated behind a retaining wall by finite element method and compared it with classical theories assuming the behaviour of soil to be elasto-plastic. Dewaikar et al. (2012)[3] proposed to evaluate active earth pressure on an inclined wall on horizontal cohesion less backfill with uniform surcharge computing with the help of Kotter's (1903) equation. Culmann (1886) considered wall friction 'δ', irregularity of landfill, any surcharges and angle of internal friction of the soil to evaluate active earth pressure, assuming a rigid plane of rupture. Culmann's graphical solution based on Coulomb's earth pressure theory was previously widely used to calculate the earth pressure of non-cohesive fill according to wedge theory.

In the present study, an attempt has been made to analyse and study the effect of different parameters like α, β, γ, ϕ for dry cohesion less soil on developed earth pressure taking into consideration, the effect of magnitude and location of concentrated point or line loading on developed active earth pressure using Culmann's graphical solution and comparing the active earth pressure magnitudes obtained using Elastic theory. The aim was to find the safe loading distance from the face of the wall where after loading does not impose additional pressure on the wall.

II. PROCEDURE

The paper is divided into three phases: (i) evaluation and analysis of the effect of individual soil parameters on active earth pressure as per Elastic theory, (ii) analysis of active earth pressure for different combination of sail parameters as obtained from Culmann's Graphical solution and (iii) comparison of magnitude of active earth pressure obtained from the above cases.

A. Effect of soil parameters on active earth pressure as per Elastic Theory

The lateral earth pressure caused by surcharge loading at a distance of L from the back face of the wall has been shown in Table 4.2.1 for variation of angle of shearing resistance (φ)and varying height of retaining structure. The stress has been evaluated at a depth z by using Theory of Elasticity from equation 2.5

$$\sigma = \frac{2q}{\pi H}\frac{a^2b}{(a^2+b^2)^2}\frac{2q}{\pi H}\frac{a^2b}{(a^2+b^2)^2}$$

Taking unit load, q=1kN/ unit length and ranging the value of "a" among 0.3, 0.5 and 0.7 and "b" ranging among 0.25, 0.50, 0.75 and 1.00 for varying height. These values from the stress distribution curve gives the maximum pressure at a depth z = bH (where, H = height of retaining wall) from the ground surface which on multiplying by the applied load gives the pressure on the retaining wall. Further in the following table the values of earth thrust has been shown taking into account a unit load acting at the above said distances.

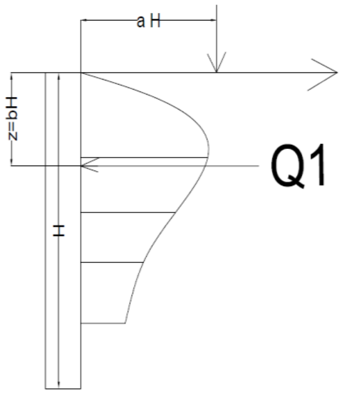


Fig. 1 Lateral earth pressure caused by load at aH distance

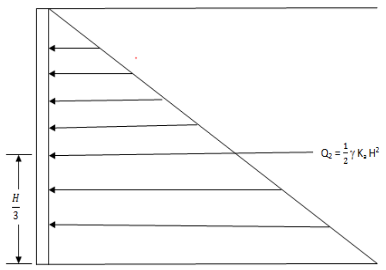
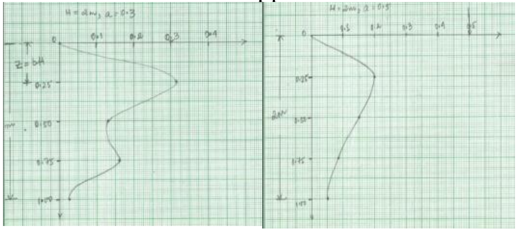


Fig. 2 Lateral earth pressure for a cohesion less soil backfill acting at a distance H/3 from base.

The total thrust by theory of elasticity is determined by adding Q_1 and Q_2 and then tabulating the value of $Q = Q_1 + Q_2$ in the following tables for variation of distance of application of load.



(a) (b)

Fig 3.: Pressure for H=2m, (a) L/H=0.3, (b) L/H=0.5

B. . Effect of soil parameters on active earth pressure as per Culmann's Theory

Culmann's considered wall friction δ, irregularity of the back fill, any surcharge loads and internal friction of the soil. The graphical solution shows the effect on wall with the application of surcharge load at different point of application with the height of the retaining wall ratio (L/H) varying from 0.3, 0.5, and 0.7.

II. RESULTS AND DISCUSSION

A. From the Culmann's graphical solution, the values of active earth thrust with the loading condition and angle of back face of wall (α=90°, 85°, 80°) and angle of inclination of back fill surface (β=0°, 5°, 10°) for different height of wall (H=2m, 4m, 6m) are calculated and the charts are prepared to find out the nature of the variation of the active earth pressure.

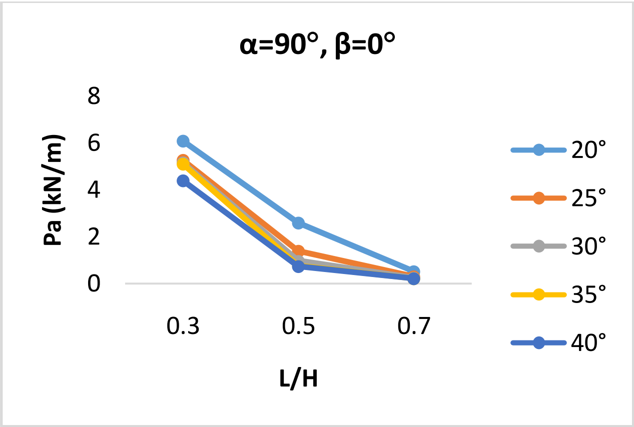


Fig 4 Variation in earth thrust for different load distance for α=90° and β=0°

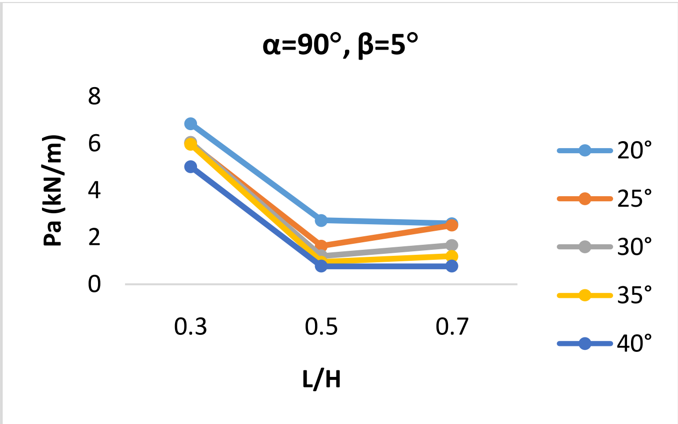


Fig 5 Variation in earth thrust for different load distance for α=90° and β=5°

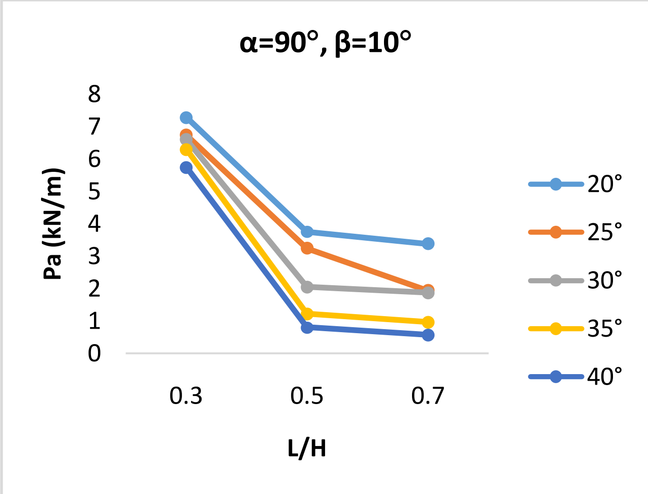


Fig 6: Variation in earth thrust for different load distance for α=90° and β=10°

From the above chart, it is concluded that for variation in angle of backface of the wall(α), for a constant angle of inclination(β), the earth thrust decreases with the increase in point of application of the load(L/H). It can be said as the load distance increases from the face of the retaining structures the action of earth thrust goes on decreasing.

From Elastic Theory, the maximum pressure is calculated and has been distinctly tabulated in Table 1.:

Table 1: Lateral earth pressure for different height of the wall on varying load application

H	L/H=		
	0.3	**0.5**	**0.7**
2m	0.274	0.223	0.206
4m	0.02	0.012	0.01
6m	0.0084	0.0055	0.0033

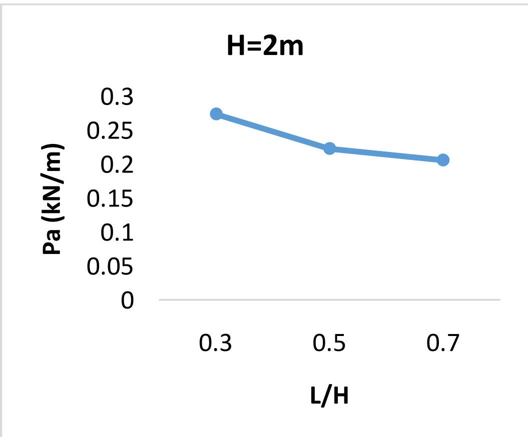


Fig 7 Lateral earth pressure variation for H=2m

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From the above charts and plots it is clear that the lateral earth pressure decreases considerably with the increase in height of the retaining structure and point of application of load from the face of the wall, indicating that the earth pressure decreaseas the load is applied at a distance from the wall.

IV. COMPARISON

From the Elastic Theory, it is seen that the lateral earth pressure for a chosen height of the wall for different point of application of load from the face of the wall goes on decreasing with the increase in angle of shearing resistance (φ). An attempt has been made to compare the earth pressure for different height of wall, which shows the increase of earth pressure with the increase in height of retaining structure. But the earth pressure decreases gradually with the increase in point of application of load which denotes the decrease in pressure as the load is applied far away from the back face of the wall.

To see the relevance and accuracy of the work done, the variation of earth thrust with the chosen height of the wall, for angle of back face of the wall (α) and angle of inclination (β) remaining 0° has been compared for both the Culmann's Graphical and Elastic Method.

The comparison shows higher lateral earth thrust obtained from Culmann's method than that from the Elastic theory. But both the method holds the similar trend of the value i.e. decreasing value of pressure with the increase in angle of shearing resistance and also decrease with the increase in L/H value.

The variation of earth thrust for different retaining wall heights under similar other boundary conditions are presented in following figure (Fig 5.2.). The plot below indicates a decreasing curve with increase in angle of shearing resistance (φ).

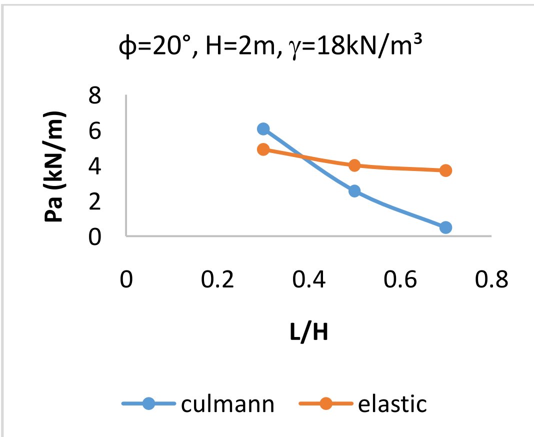

Fig 8 Variation of the pressure with the L/H ratio for φ=20° for H=2m by Elastic theory and Culmann's solution

Thus, it can be concluded from Fig 7, that active earth pressure is more when evaluated using Culmann's graphical solution as compared to the values obtained from Elastic theory.

At φ= 20°, pressure is maximum for both cases, value of which is evaluated to be 6.077 kN/m from Culmann's solution and 0.274 kN/m from Elastic theory. Magnitude of earth thrust decreases with increase in φ and is observed to be lower when calculated by Elastic theory (0.206 kN/m) than that obtained using Culmann's graphical method (6.077 kN/m). Similar trends of curves were obtained using L/H= 0.5 and 0.7.

From the above comparison curve it is seen that the earth pressure value of Culmann's solution is more than that of elastic theory. The earth thrust decreases with the increase in point of application of load from the face of the wall indicating the decrease in earth pressure with the increase in distance thus indicating the safe distance from the wall face.

V. CONCLUSION

The work which is done by Elastic theory and Culmann's graphical solution, shows the safe distance of carrying out any civil engineering work near a prevailing structure and also to find out the maximum active earth pressure under loading conditions. The work gives the maximum earth pressure for surcharge loading at a l/h distance from the face of the retaining wall.

It is viewed that the values of lateral earth pressure decreases with the increase in the distance of the load from the face of the wall which implies that the loading near the face of the wall exerts more pressure on the wall. Also, it is deciphered that for a chosen α-angle and β-angle, the earth thrust decreases with the increase in point of application of load. This can be said that as the load distance increases from the face of the retaining structure, the action of earth thrust decreases

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REFERENCES

[1] F. A. Salman, Y. J. Al-Shakarchi, H. M. Husain and D. K. Sabre, "Distribution of earth pressure behind retaining walls considering different approaches", *International Journal of the Physical Sciences*, vol. 5, pp. 1389-1400, 2010.

[2] B. M. Das, *Principles of Foundation Engineering*, 6th ed, J. Ross publishing, Florida, 2010.

[3] D. M. Dewaikar, S. R. Pandey and J. Dixit, "Active Thrust on an Inclined Retaining Wall with Inclined Cohesionless Backfill due to Surcharge Effect", ISRN Soil Science, vol. 2012, pp. 1-8, 2012.

[4] B. C. Punmia and A. K. Jain, *Soil Mechanics and foundations*, 16th ed., Firewall media publishers, India, 2005

[5] Swiss Standard SN 670 010b, Characteristic Coefficients of soils, Association of Swiss Road and Traffic Engineers