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BEHAVIOUR OF SLOPES CARRYING FOOTING LOAD

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Abstract—
: Footing resting on or in vicinity to a slope presents a special problem in foundation engineering. Research had been divided into two different sections one is dealing with critical load carried by slope profiles at various edge distance. While the other is stability evaluation of such slopes bearing the foundation loads.

The research article deals with stability evaluation of unreinforced carrying various configuration and intensity of footing load. The stability evaluation of slopes bearing foundation loads is conducted using PHASE2 software. A design chart will be developed to correlate the stability of slope expressed in terms of critical load and configuration of slope and footing.

Keywords: **- critical load, configuration of slope, footing load, unreinforced slope, design chart**

I. INTRODUCTION

Foundations are sometimes placed on slopes, adjacent to slopes, or near a proposed excavation. Presently in the case of bridges, footings are usually not placed within the fill; instead, pile or other foundations are considered. These alterations may not be most economical. Foundations are also sometimes situated near the open section of the underground railways. In such a situation, the problem becomes that of obtaining the minimum value of the bearing capacity: (1) From foundation failure; and (2) from overall stability of the slope.

For footing in the case of non-cohesive soil, the bearing capacity will always be governed by the foundation failure, while in cohesive materials, the bearing capacity of the foundation may be limited by the stability of the whole slope. When the foundation is constructed on slope, the bearing capacity is found to be much lesser than that of plain ground. Similarly, the stability of slope due to placement of new footing or increase in existing load may also affect.

In the assessment of slopes, engineers primarily use factor of safety values to determine how close or far slopes are from failure. Conventional limit-equilibrium techniques are the most commonly-used analysis methods. Recently, however, the significant computing and memory resources available to the geotechnical engineer, combined with low costs, have made the Finite Element Method (FEM) a powerful, viable alternative

In this paper, finite element method is used to analyze the slope profile, to obtain its stability as well as critical load carried by slope, with different slope configuration.

Firstly, a slope profile having constant parameter C, ɸ, H and ɣ, (where C is cohesion value in KN/m2 ,ɸ is friction angle in degree, H is height of slope in meter and ɣ is unit weight of soil in KN/m3) has been selected, and then the slope configuration factor that is angle of slope and edge distance of footing are varied.

Slope is loaded with UDL for foundation load at different edge distances for constant dimension of foundation (10% of H).

Then, the various configuration for SRF value 1 has been analyzed and the critical load is found out with the help of PHASE2 software, which works on the finite element method. For various loads at different angle of slope and edge distance a curve is plotted between edge distance at X axis and critical load at Y axis for constant C/ ɣHtanɸ value. Such slope profiles has been considered which are stable that is having a factor of safety greater than 1, so the structure or foundation constructed on it are stable.

II. LITERATURE REVIEW

Meyerhof (1957) studied the problem of ultimate bearing capacity of foundation on slope. The full formation of shear zones under ultimate loading condition were not possible on the sides which were closed to the slope, and therefore supporting capacity of soil on that side get considerably reduced. The bearing capacity of foundation on or near the slope was found to be lesser than that of plain ground. The ultimate bearing capacity equation on or near the slope and design charts shows that bearing capacity depends upon distance of foundation from top of the slope, angle of slope, angle of shearing resistance of soil and depth to width ratio of the foundation. Gemperline (1988) reported the results of 215 centrifuge tests on model footings located at the top of a slope of cohesionless sand. Based on these experiments evidence, he

SLOPE PROFILE –I	SLOPE PROFILE –II
Material elastic property: - Isotropic	Material elastic property: - Isotropic
Cohesion (C):- 30KN/m2	Cohesion (C):- 25KN/m2
Friction angle (ɸ):- 35 degree	Friction angle (ɸ):- 28 degree
Unit weight (ɣ):- 21KN/m3	Unit weight (ɣ):- 16KN/m3
Young’s modulus: - 50000 kpa	Young’s modulus: - 50000 kpa
Poisson’s ratio: - 0.3	Poisson’s ratio: - 0.3
Material type: - plastic	Material type: - plastic
Slope height:-20m	Slope height:-10m

proposed an equation that would enable foundation engineers to determine the bearing capacity factor which found to be useful in calculation bearing capacity for footings of different size and shapes, located anywhere in the region at the top of the slope.

Bowels (1997) studied the problem of ultimate bearing capacity of foundation on and adjacent to slope and recommends that, the bearing capacity was depending upon angle of shearing resistance, slope inclination, depth of foundation and location of foundation which was adjacent to slope. He also recommended a classical ultimate bearing capacity equation for calculating bearing capacity on slope.

Kumar and Ilamparuthi (2003) studied the response of footing on sand slope. They carried out investigations for three different slope angles and three different edge distances and concluded that the load-settlement behavior and bearing capacity can be improved by inclusion of geosynthetic reinforcement under the footing. Further the bearing capacity decreases with increase in slope angle and decrease in edge distance both in reinforced and unreinforced slopes.

Shiau et.al. (2011) studied undrained stability of footings on slopes to obtained solutions for the ultimate bearing capacity of footings on purely cohesive slopes by applying finite element upper and lower bound methods. In a footing on slope system, the ultimate bearing capacity of the footing may be governed by either foundation failure or global slope failure.

Zhan and Liu (2012) studied the undrained bearing capacity of footings on slopes and investigated the combined bearing capacity behavior of strip footings on the top of undrained soil slopes under vertical load and overturning moment, as well as purely vertical bearing capacity for footings adjacent to slopes, by using the finite element analysis method. Typical vertical load displacement curves obtained from the finite element analyses for different slope angles

III. SLOPE MODELLING-

SELECTION OF SLOPE PROFILE -In this paper, two slope profiles has been considered which have specified soil constants, and represent a typical at situ slope section, for each profile, some basic parameters such as cohesion, friction angle, modulus of elasticity, Poisson ratio, unit weight of soil etc are defined. For constant parameter the slope angle is varied and slope profiles are constructed.

Such slope is considered which is stable, that is, having a factor of safety greater than 1, so the structure or foundation constructed on it is stable. Both slope profile different with each other in C, ф value along with their height, so they can represent actual condition of field and behavior of slope so other slopes can be easily analyzed by comparison with these. Mohr-coulomb criteria has been used for analysis and assume plastic equilibrium of slope and also divided complete profile into 1500 triangle and limit equilibrium analysis performed on 6 nodes of each triangle**.**

Properties of profile:-

(a) ANALYSIS OF SLOPE PROFILE:-I

The hit and trial method is used to analyze the slope profile and the critical load corresponding to SRF value 1 is calculated.

Edge distances are increasing in order of 10% of H.

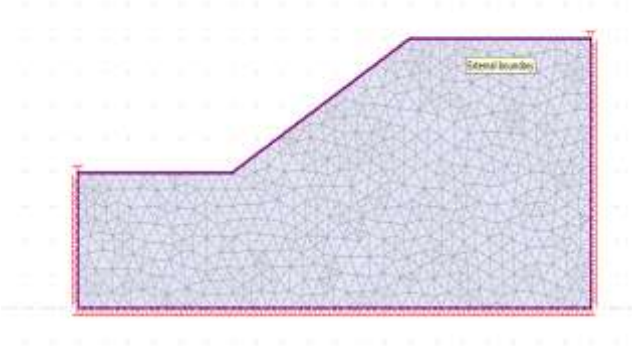


Fig. 1: Slope configuration-I (at slope angle 30 deg)

For each slope profiles, 3 slope configurations are considered i.e. at 30 degree, 45 degree and 60 degree. The critical load is applied at slope profile I in order of 2m, 4m, 6m, 8m and 10m edge distances and analyzed by PHASE2 and the critical load is represented in the form of table.

Table I for critical load

edge distance(m)	load(KN), 30deg	load(KN), 45deg	edge load(KN), 60deg
2	1320	758	220
4	1550	1020	270
6	1700	1205	380
8	2050	1500	530
10	2200	1900	730

(b) ANALYSIS OF SLOPE PROFILE:-II.

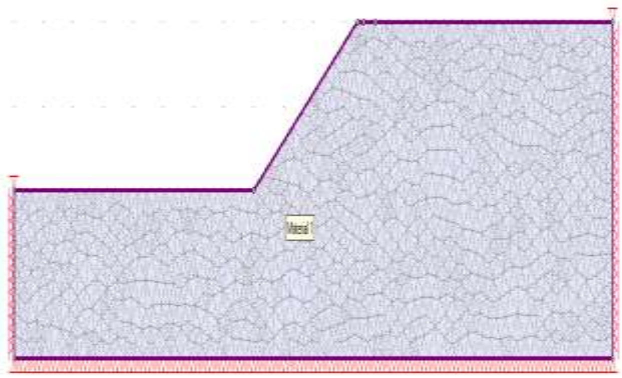


Fig. slope configuration-II (at slope angle 30 deg)

Similarly for slope profile II the critical load is calculated at 1m, 2m, 3m, 4m, 5m edge distances and analyzed..

Table II for critical load.

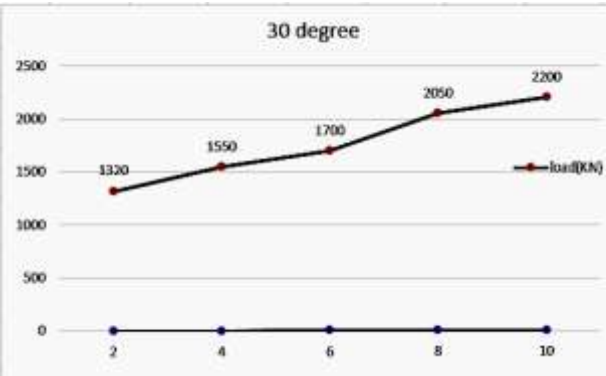
edge distance(m)	load(KN), 30deg	load(KN), 45deg	edge load(KN), 60deg
1	490	310	170
2	595	400	185
3	680	450	225
4	735	510	270
5	840	560	325

IV. RESULTS

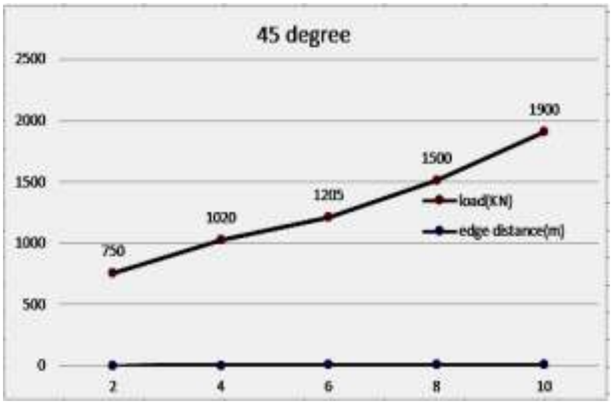
Graph between critical load and edge distances

From the analyses of slope profile I, the curve is plotted between critical load and edge distances to show the variation of critical load with increasing in edge distances.

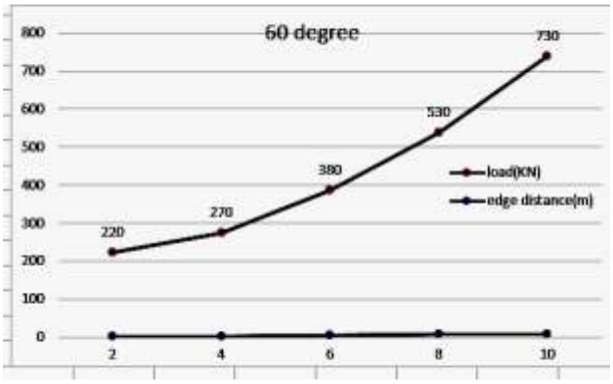
Graph is plotted corresponding to a constant value of **C/ ɣHtanɸ.**



Graph (1)

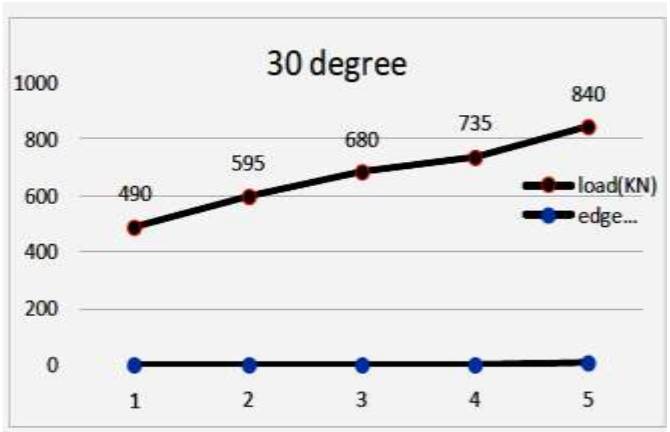


Graph (2)

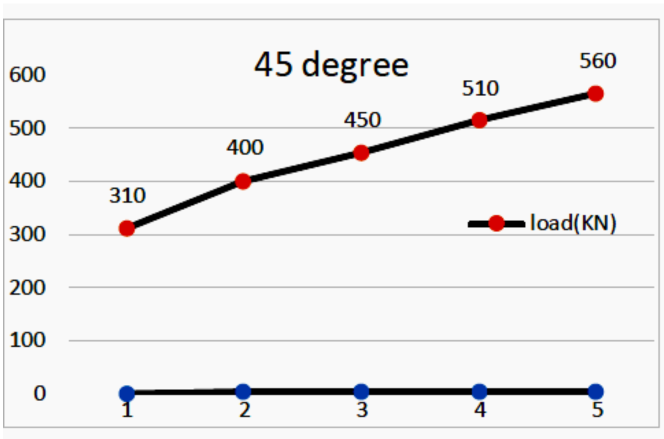


Graph (3)

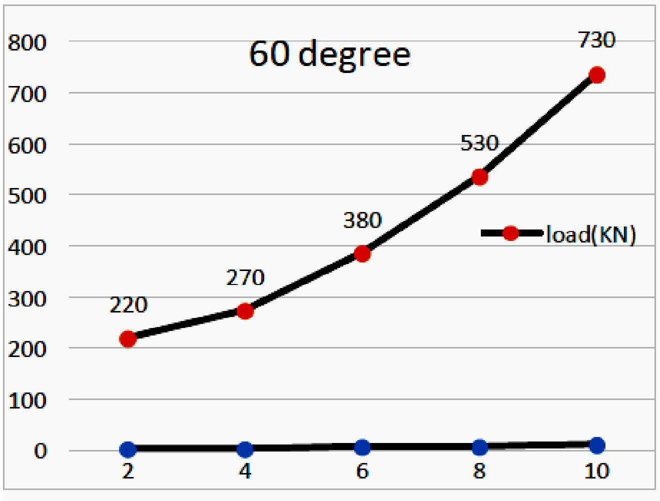
Case II: C/ ɣHtanɸ= 0.2939



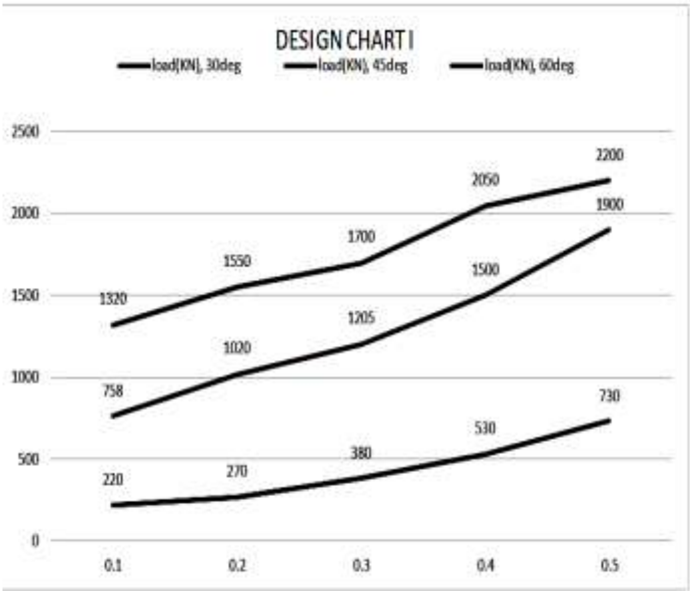
Graph (4)

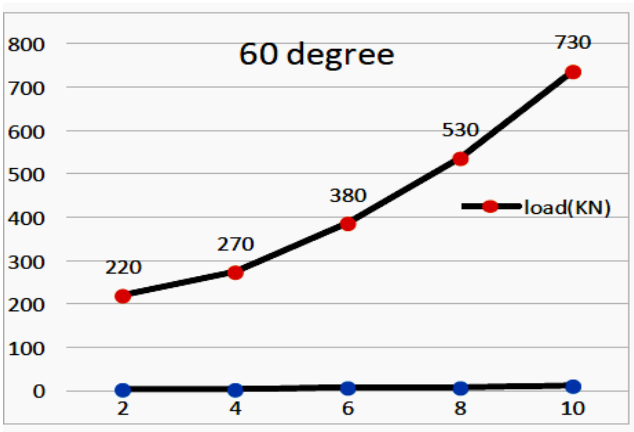


Graph (5)

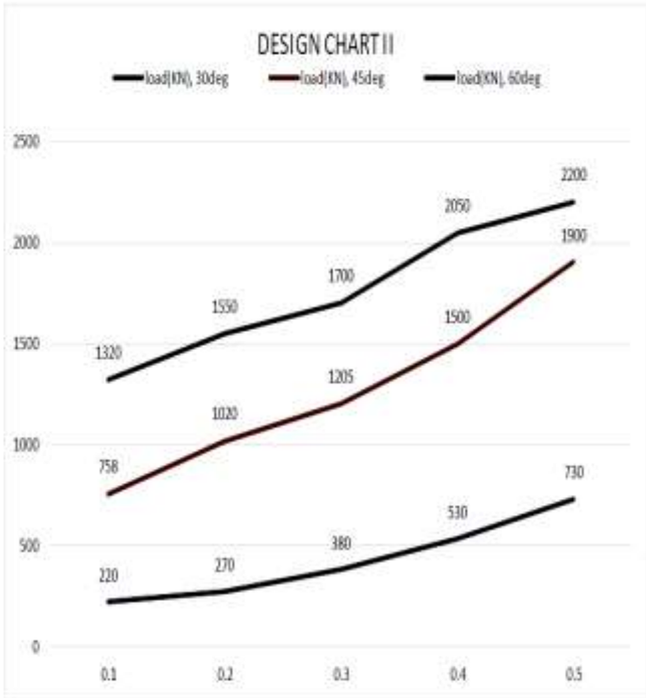


Graph (6)





Graph (7)



V. DISCUSSION

On the basis of above analysis and charts which are prepared between critical load and edge distances, design charts have been plotted. Charts are used for the calculation of maximum or critical load directly by knowing some slope parameter.
Charts are plotted between normalized edge distances and critical load, where normalized edge distance is the ratio of edge distance and slope height. From the design chart after calculating parameters C, ϕ, γ and H and constant C/ $\gamma H\tan\phi$, we can calculated critical load at various edge distance.

VI. CONCLUSION

The stability analysis of slopes were carried out on different slopes having different inclinations, slope profiles, soil parameters and footing loads with various footing locations using PHASE2 software. The result shows that for a specific slope, slope height and edge distance of footing load from the slope, influences the maximum load on the slopes at critical condition.

The critical load on the respective slopes increases when the edge distances of the footing load from the slope increases and it decreases when the height of slope decreases. The critical load also changes with inclination angle. When the angle of inclination of slope increases, the Strength Reduction Factor (SRF) value of the slope starts decreasing and hence the critical load also decreases. It is also observed that there is no possibility to construct any footing near to the slope at some greater inclination angles (such as the inclination angles equal to and greater than 75 degree). In such cases, the SRF value was found to be less than 1 and hence the slope cannot bear the footing load at the specified distance near to the slope. From two design charts it is observed that, for the different soil parameters (i.e. cohesion value of soil, friction angle and unit weight), the critical load and the SRF value of the slope shows variation.

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