Numerical Analysis of Bearing Capacity of Strip Footing Adjacent to Cohesionless Soil Slope

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***Abstract*—Nepal being a mountainous country with varying topography and slope, the foundation on slopes is inevitable. Thus bearing capacity of the foundation near slope is the primary concern and provide baseline for any structural design. This paper presents the analysis of the strip foundation problem near slope with consideration of various parameter like slope angle, footing distance from the crest and depth width ratio. Finite element method is used to evaluate the bearing capacity using Plaxis 2D. The results obtain from this research project includes determination of the bearing capacity under different parametric condition and established the relation of it with different geometrical as well as strength parameters in the form of graphs.**

***Index Terms*—Bearing capacity, Strip Footing, Finite Cohesion-less slope soil, Numerical Analysis.**

I. Introduction

Foundations are an essential component of any structure and have a primary purpose of transferring concentrated loads produced by a structure to the underlying foundation material. Some common examples of such foundations include basement excavations for high-rise buildings, bridge abutments and tower footings for electrical transmission etc.may required to construct on the slope. Bearing capacity of foundation on the level ground is solely controlled by the shear strength of soil under foundation and settlement criteria whereas the foundation near proximity of the slope required consideration of stability of the slope. Thus when a foundation is constructed near a slope additional design parameters are to be considered that are often difficult to evaluate thus making the design process complex and drawn out. Influencing geometrical parameter of slope like height of slope, inclination of slope, setback of footing from crest of slope and characteristics of soil and proximity of structure near slope affect load that a soil can carry, the load usually reduces than in case of flat ground. In this paper, the ultimate bearing capacity of strip footing located on the top of slope is investigated using finite element analysis software Plaxis 2D. It includes footing responses to the various parameters including slope angle, footing distance ratio, and depth of embedment. Throughout the history of the foundation, design and construction of foundation near a slope has been problem for many engineers. Thus it has been the subject of numerous studies. Several studies have been done in past related to the bearing capacity. Terzaghi [1] has been the pioneer to study the bearing capacity of shallow strip footing under vertical load in horizontal ground and put forward the equation, which is extensively used nowadays. Modification has been made in the equation with different factors slope factors, depth factors and shape factors by various researchers Meyerhof, Hansen and Vesic. Meyerhof [2] investigated the theory of slope stability along with the general failure mechanism of foundation on level ground and presented the graph for bearing capacity of foundation on purely cohesion-less soil and cohesive soils adjacent to the slopes. After Meyerhof, Hansen [3] and Vesic [4] evaluated the bearing capacity for the foundation on slope crest. Saran et al. [5] extensively studied failure mechanism in the slope and the developed analytic solution of ultimate bearing capacity adjacent to the slope using two different approach limit equilibrium and limit analysis. Bearing capacity is always governed by the foundation failure in case of non-cohesive slope soil and slope stability for cohesive slope soil [5]. Graham et al. [6] paid attention to modeling asymmetric non falling zone beneath the footing along with stress distribution on the footing base (method of stress characteristic) for cohesionless slope soil. Using upper bound solution, the effect of various loading and geometrical condition on the $N\gamma$ were studied and procedure adopted for the determination of critical failure mechanism found to be efficient [7].

II. Methodology

Numerical analysis method is adopted for the bearing capacity analysis of the footing near cohesionless slope soil.In the study, finite element software plaxis 2D was used to calculate bearing capacity of strip footing located near cohesionless slope under vertical load. The strip footing of width 2 m was taken. Boundary condition applied in the model is such that left and right boundary are restrained movement in horizontal direction whereas the bottom boundary is restrained form both horizontal and vertical direction. The soil field was modeled of width of 35 m to 55 m (In order to perform parametric analysis) and depth of 20 m in order to eliminate the boundary effect due to loading. Geometric model used in the analysis are shown in Fig.1

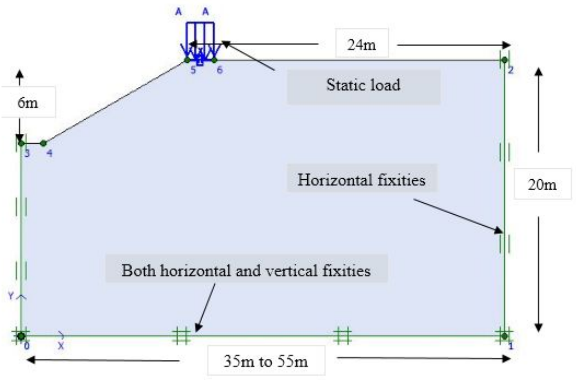

Fig. 1. Geometry Model

Different mesh density in the soil model are generated during analysis, closeness of the results found to be with number of elements approximately at 400 number of Meshing is done by 15 nodded triangular element with two layer of different mesh density, fine at top and medium at bottom, which is shown in Fig. 2. Accuracy of model is acquired by validation of model which is done by the optimization of model size and mesh convergence analysis as per the different literature value for the footing on the level ground.

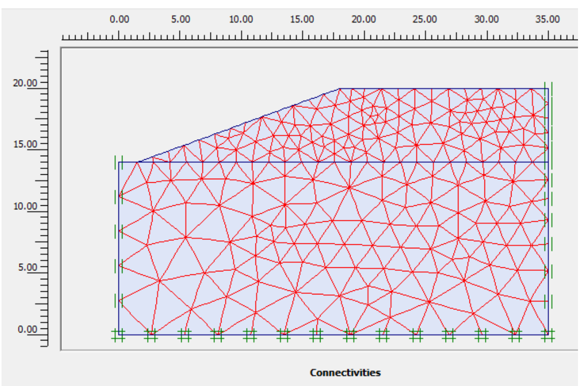

Fig. 2. Typical mesh shape

The soil mass is assumed to be homogeneous obeying a Mohr coulomb's strength criteria. Pore water effect are not considered in the present study. Geotechnical parameters and different geometries for cohesionless soil used in present study for modeling are tabulated in Table I and Table II.

TABLE I
GEO-TECHNICAL PARAMETERS CONSIDERED IN THE ANALYSIS

Parameters	Values
Unsaturated Unit Weight of soil, $\gamma(KN/m^2)$	17
Friction Angle of soil, ϕ (degree)	35
Cohesion of soil,c (KN/m^2)	0.02
Earth pressure coefficient at rest,K_o	0.426
Young's modulus of elasticity, E (kN/m^2)	15000
Permeability in both directions,(m/day)	1
Poisson's ratio, ν	0.3
Drainage type	Drained

TABLE II
GEOMETRICAL PARAMETERS CONSIDERED IN THE ANALYSIS

Parameters	Values
Width of footing,B	2 m
Height of slope, H	3B
Slope angle, β	10,20,30 and 35
Depth width ratio, d/B	0,0,5 and 1
Footing distance ratio, b/B	0,1,2,3 and 4

III. RESULT AND DISCUSSIONS

The study concluded with total of 63 numbers of models with different geometrical parameters which is mentioned in table. The model output (load settlement curve) are used for the determination of ultimate bearing capacity of each model. The typical output and load-settlement curve is shown in fig. 3 and fig. 4 respectively.

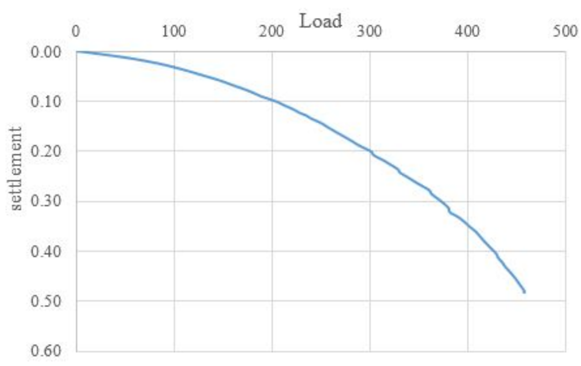

Fig. 3. Typical load settlement curve

A. *Effect of footing distance ratio*

The results indicate that the ultimate bearing capacity increases with increase in the distance of footing from crest slope. Further when the footing is moved from slope crest (b/B=0) to increased footing distance ratio, there is increase in the ultimate bearing capacity however the rate of increase in bearing capacity is decreases with increase in the footing distance ratio. The rate decreases until b/B =3.5 for depth width ratio, d/B=0 and footing on surface whereas for other depth

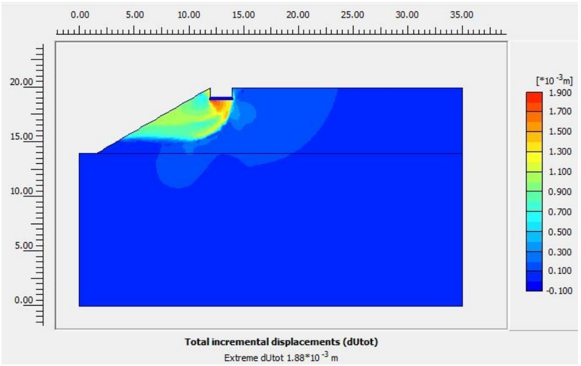

Fig. 4. Typical Output

of embedment, slope effect appears to diminishes at greater distance footing ratio. This indicate that ultimate bearing capacity of footing on slope approaches to the footing on level ground. The slope effect to the footing near slope crest is attributed to the soil passive resistance from the slope side. The effect of footing distance ratio is shown in fig. 5 to fig. 7.

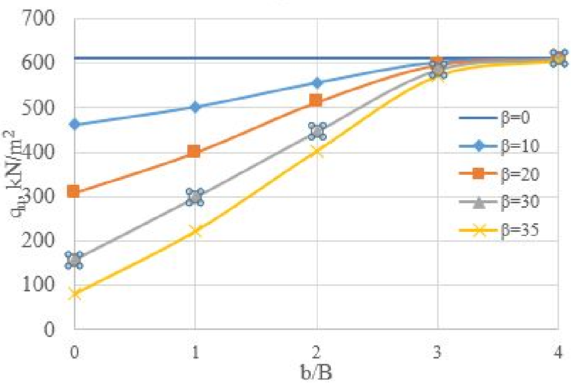

Fig. 5. Effect of footing position at d/B=0

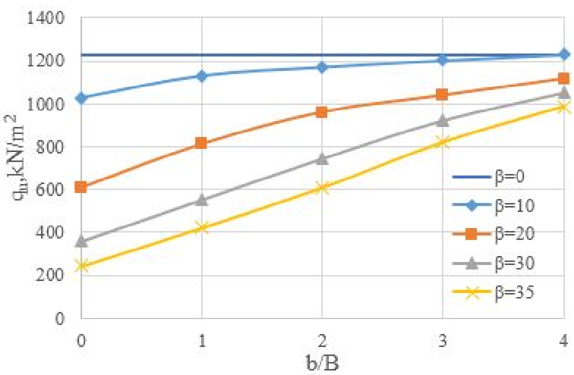

Fig. 6. Effect of footing position at d/B=0.5

B. Effect of slope angle

The results indicate that with the increase in the slope angle, the bearing capacity decreases. At high slope angle, rate of reduction of bearing capacity is high and also depend on the footing width ratio

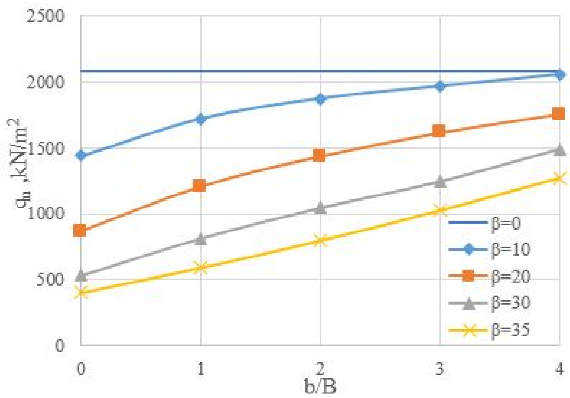

Fig. 7. Effect of footing position at d/B=1

whereas at low slope angle, effect of footing width ratio is very less than compared to high slope angle.

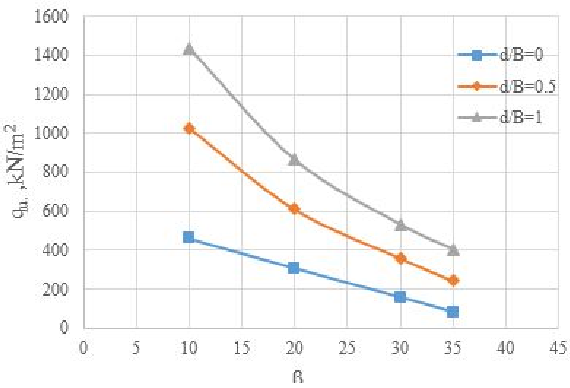

Fig. 8. Effect of slope angle

C. Effect of depth of embedment

The result indicate that with increase of depth width ratio bearing capacity increases. Embedment of footing imposed surcharge load of soil above the footing and thus increases the bearing capacity. There is constant increase in the bearing capacity.

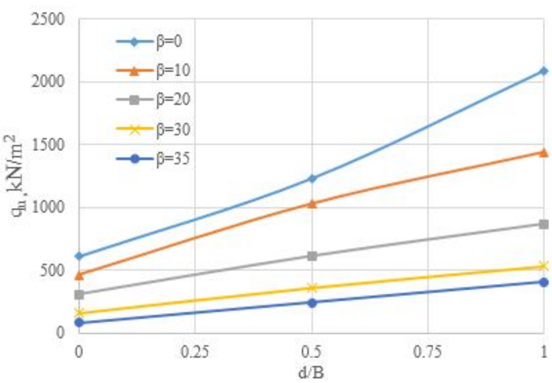

Fig. 9. Effect of depth of embedment

D. Comparison of result

The results obtained from the model analysis for the footing on the crest for different slope angle subjected to static load condition are summarized and compared with bearing capacity calculated using various bearing capacity theories such as Graham et al. [6], Meyerhof [2],Saran et al. [5] and Zhu [7]. The bearing capacity obtained from analysis shows in good agreement with the other literature.

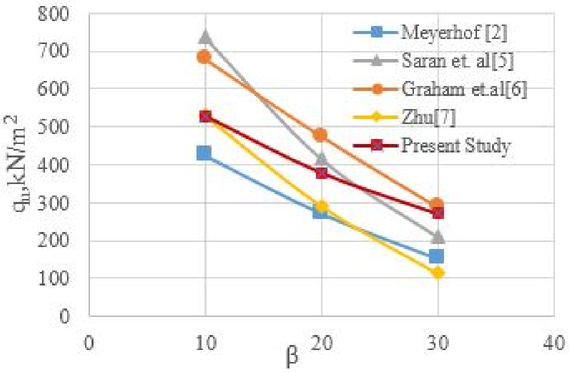

Fig. 10. Comparison with different literature

IV. Conclusion

Parametric analysis on the ultimate bearing capacity of the footing placed on the finite slope has been performed using the Plaxis 2D under static as well as in seismic conditions. Some of the conclusions are drawn which is shown below:

- There is considerable effect of different factors (slope angle, footing distance from the crest, depth of embedment) on the bearing capacity of footing on near sloped soil.
- Lowest bearing capacity value is observed in the case of footing on the crest of slope.
- Bearing capacity increases as the footing placed away from the crest until the slope effect diminishes.
- Failure due to slope instability increase as the slope angle increase thus reduces the bearing capacity.
- At the low slope angle value, the effect of footing distance ratio is less sensitive as compared to higher slope angle.

Acknowledgment

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References

[1] K. Terzaghi, “Theoretical soil mechanics. johnwiley & sons,” *New York*, pp. 11–15, 1943.

[2] G. Meyerhof, “The ultimate bearing capacity of foundations on slopes,” in *Proc., 4th Int. Conf. on Soil Mechanics and Foundation Engineering*, vol. 1, 1957, pp. 384–386.

[3] J. B. Hansen, “A revised and extended formula for bearing capacity,” 1970.

[4] A. S. Vesić, “Analysis of ultimate loads of shallow foundations,” *Journal of the Soil Mechanics and Foundations Division*, vol. 99, no. 1, pp. 45–73, 1973.

[5] S. Saran, V. Sud, and S. Handa, “Bearing capacity of footings adjacent to slopes,” *Journal of geotechnical engineering*, vol. 115, no. 4, pp. 553–573, 1989.

[6] J. Graham, M. Andrews, and D. Shields, “Stress characteristics for shallow footings in cohesionless slopes,” *Canadian Geotechnical Journal*, vol. 25, no. 2, pp. 238–249, 1988.

[7] D. Zhu, “The least upper-bound solutions for bearing capacity factor $n\gamma$,” *Soils and foundations*, vol. 40, no. 1, pp. 123–129, 2000.