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Bearing Capacity of Footings Near Slopes

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ABSTRACT:
Sloping ground near the footings have an adverse effect on their performance. Slope increases the settlements of the footings and while it reduces their bearing capacity. In the present paper, a footing with rough base has been considered for the analysis. The bearing capacity factors have been determined with the consideration of resistance of soil above the foundation level. A simple limit equilibrium method has been used to evaluate bearing capacity. The parameters considered for the analysis include the distance between edge of slope and center of footing, slope angle and foundation depth. It is observed from the analysis that bearing capacity reduces as distance between footing and the edge of the slope decreases. Increase in slope angle cause the reduction in the bearing capacity.

Key words: Bearing capacity, Footings, Limit equilibrium method, Slopes.

1- Introduction

A foundation is a part of the structure which transmits the load of the structure and substructure onto the underlying soil. Foundations are commonly divided into two categories; shallow and deep foundations. Shallow foundations are most commonly used foundation which are having depth to with ratio less than one. In general, shallow foundations are more economical to construct compared to deep foundations and generally used when underlying strata having sufficient bearing capacity and structure having low weight [1]. Analysis and design of a shallow foundation is simple compared to deep foundation design. Failure of a shallow foundation may occur in two ways; first by shear failure of the soil supporting the foundation, and second by excessive settlement of foundation [2]. Shallow foundation passes some disadvantages like excessive settlements, limited capacity, and design problems in irregular and sloping ground. Moreover it cannot perform well under pull-out, torsion and moment loading. Quite often, structures are built near the slopes or on the slopes due to either land limitation or due to any other specific reason, such as construction of bridges, for architectural purposes. Ultimate bearing capacity of the foundations is significantly affected by the presence of the slope [3]. The bearing capacity of the foundation is a primary concern in the field of foundation engineering and accurate determination of bearing capacity on slopping ground is a challenging task for an engineer [4]. The geotechnical design of foundations near the crest or on the slope of a slope includes the consideration of various factors such as slope angle, depth ratio, angle of internal friction and crest distance between foundation and slope edge. There are different methods available for estimation of bearing capacity of foundation on slopes. Bearing capacity analysis of foundations can be made by using four approaches; slip-line methods, limit equilibrium methods, limits analysis methods and numerical methods. [4-19] have determined the bearing capacity of foundation on slopping ground using various methods. Limit equilibrium analysis are very popular in foundation engineering to determine the bearing capacity. Limit equilibrium method has been used in present study.

Volume 1, No.1, pages:9-14

2- Analysis method

A rigid footing with rough base is placed on sloping ground having width B and depth D. Soil has been assumed as a homogenous and isotropic material. It is assumed that soil is elastoplastic material and failure is governed by Mohr–Coulomb failure criterion and principle of superposition is valid. A limit equilibrium method has been used in for evaluation of bearing capacity of strip footing on sloping ground. The failure mechanism consists of three zones - a triangular active wedge (ABC), a log spiral radial shear zone (ACD) and a triangular passive wedge (ADE). Soil above the AE has treated as overburden pressure. It has been assumed that passive force acting on opposite to slope site is not utilized perfectly and a mobilization factor 'm' has been introduced to use the mobilized shear strength for consideration. Value of mobilization factors were adopted from [5]. For determination of Nc, soil is assumed to be weightless and without surcharge load. Nγ values are determined by assuming soil as a cohesion less material and without surcharge loading. Similarly Nq is determined by assuming soil as a weightless and cohesion less material. The shear resistance on flat side (BCJ) is assumed to be given by:

$$\tau_m = c_m + \sigma' \tan(\varphi) \qquad (1)$$

Where c_m and φ are mobilised cohesion and mobilised internal friction angle respectively. Fallowing steps are involved in the determination of bearing capacity factor. (I) First length of FA, AE, DK and IL has been determined, (II) Passive resistance acting on DK and IL is determined (Fig. 2), (III) Moment of all forces about point A is determined by considering equilibrium of all force. (IV) Passive resistances acting on wedge ABC are determined by considering all equilibrium of all forces acting on wedge ABC (Fig. 3). (V) N_C, Nq and Nγ value were determined for different value of friction angle, slope angle and offset distance between foundation and slope edge.

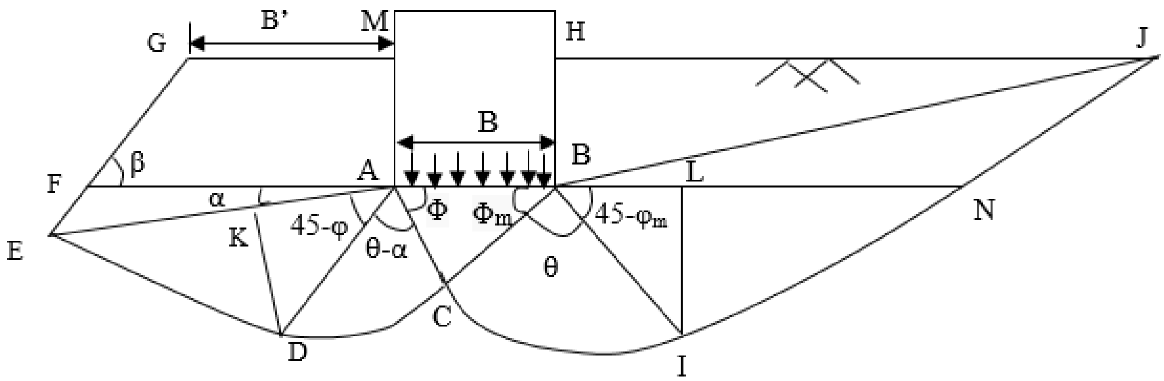

Fig. 1. Failure surface considered in analysis.

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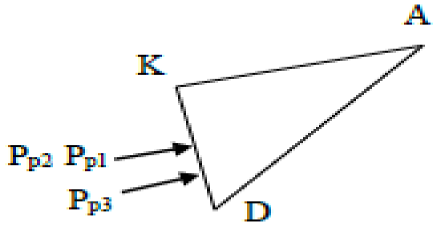

Fig. 2. Passive force on plane KD.

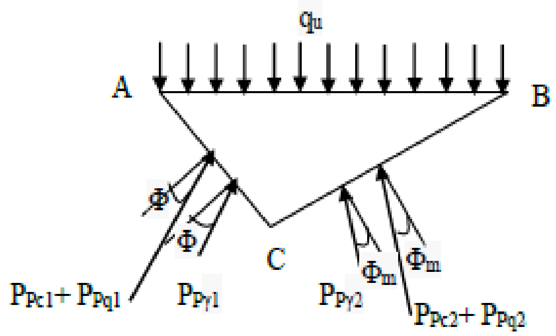

Fig. 3. Force acting on wedge ABC.

Assuming principle of superposition is valid, bearing capacity factors are determined. Bearing capacity factors are theoretically similar to [5] but magnitudes are different. Values of bearing capacity factors Nc, Nq and Nγ are given by Eq. 2, Eq. 3 and Eq. 4 respectively.

$$N_c = \frac{P_{pc1} + P_{pc2}}{cB} + \frac{(1+m)\sin\phi\sin\phi_m}{\sin(\phi+\phi_m)} \quad (2)$$

$$N_q = \frac{P_{pq1} + P_{pq2}}{\gamma DB} \quad (3)$$

$$N_\gamma = \frac{2P_{p\gamma1} + 2P_{p\gamma2}}{\gamma B^2} \quad (4)$$

3- Results

Parametric studies have been performed to determine the effect of slope angle, offset distance between slope crest and foundation, depth ratio of footing on bearing capacity factors. For parametric study, constant values of angle of internal friction have been assumed. Results for a particular value of angle of internal friction are presented and discussed here.

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3.1. Effects of slope

Bearing capacity factors are reduced with increase in the slope angle. Effect of slope on bearing capacity factors are shown in Fig. 4-6.For higher slope angle the rate of reduction in bearing capacity is high and same time it depends on offset distance as well. At the low slope angle the effect of offset is very less compared to higher slope angle. Effect of slope angle is more prominent in N_γ value compared to other two bearing capacity factors.

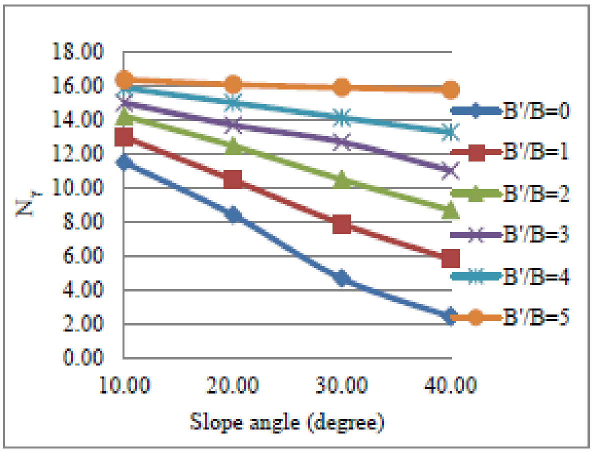

Fig. 4. Effect of slope angle and offset distance in Nγ value for Φ =300 and D/B=0.5.

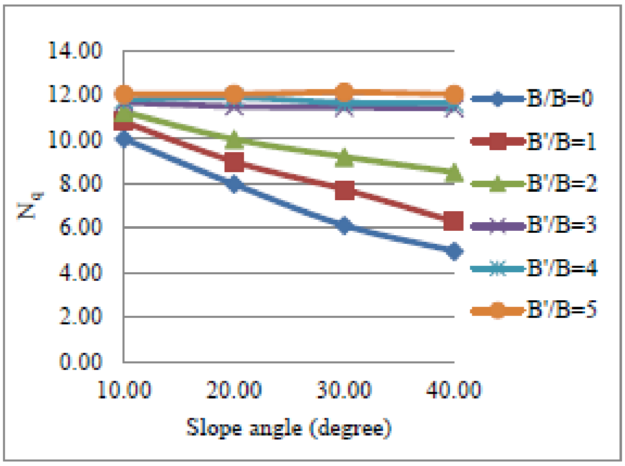

Fig. 5. Effect of slope angle and offset distance in Nq value for Φ =300 and D/B=0.5.

3.2. Effects of offset distance

With increase in offset distance bearing capacity factors have been increased. Effect of offset distance on bearing capacity factors are shown in Fig. 4-6.On interesting observation in present analysis is that the effect of slope angle becomes negligible when B'/B approaches approximately equal to or more than 5.

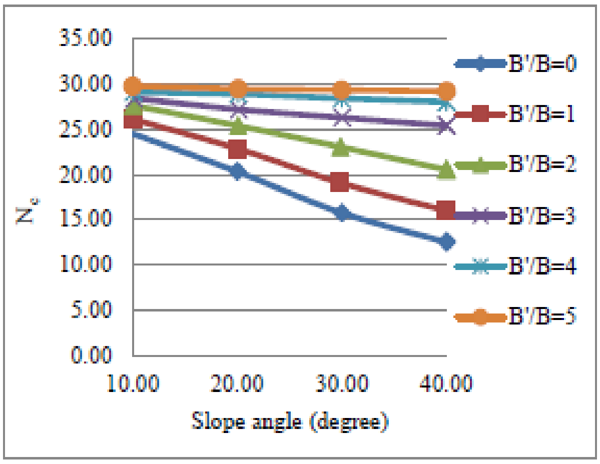

Fig. 6. Effect of slope angle and offset distance in Nc value for Φ =300 and D/B=0.5.

3.3. Effects of depth ratio

Bearing capacity factors are increased with increase in depth ratio. The effect of depth ratio is very prominent at a lower slope angle compared to high value of inclination. Effect of depth ratio on Nq value is shown in a Fig. 7. Similar observations are made for other bearing capacity factors, Nγ and Nc.

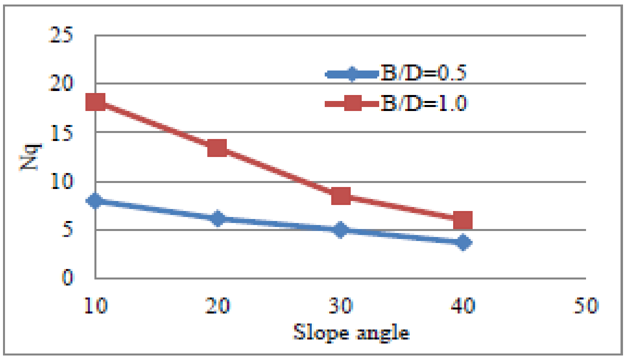

Fig. 7. Effect of depth ratio on Nq for Φ =30^{0}.

4- Conclusion

Effect of slopping ground on bearing capacity is influenced by various factors such as depth ratio of footing, offset distance between footing and slope edge as well. Bearing capacity factors have been increased with increase in depth of foundation. Effect of slope angles becomes negligible when B'/B approaches approximately equal to or more than 5. At the low slope angle value, the effect of offset is very less as compared to higher slope angle. The effect of depth ratio is very prominent at a lower slope angle compared to high value of inclination.

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