Numerical Analysis for Undrained Bearing Capacity of Eccentrically Loaded Footings near Slopes

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ABSTRACT

Estimating bearing capacity of foundations is one of the key issues in geotechnical practices. Footings have to be built on slopes or near the crest of slopes in some civil engineering practices. This study investigated the combined bearing capacity behavior of strip footings near undrained soil slopes under VM loading conditions, as well as vertical bearing capacity, using the finite element analysis method. Factors, such as soil properties, slope angle, slope height, footing location from crest of slope, which affect the bearing capacity behavior of foundations, are analyzed through parameters studies. Failure load envelopes in VM load space for some cases are presented and suggestion is made for future studies of this problem.

KEY WORDS: Bearing capacity; slope stability; finite element analysis; combined load

INTRODUCTION

Estimating bearing capacity of foundations has been one of the key issues in geotechnical practices. There are lots of investigations addressing this topic using analytical, empirical and numerical methods. Most of these results are usually expressed as a superposition formula in the form of the equation for strip footings, proposed by Terzaghi (1943). For example, Meyerhof (1951), Hansen (1952), and Vesic (1973) extended Terzaghi’s equation by adding factors to account for different footing shape, foundation embedment and inclined loading. More recent studies were to determine these factors using limit analysis or finite element analysis methods (Hjiaj et al, 2005; Zhan et al, 2008). The general ultimate bearing capacity equation can be expressed as

\[ q_u = c N_{c} \lambda_{c} \lambda_{q} + q N_{q} \lambda_{q} \lambda_{q} + 0.5 B \gamma N_{b} \lambda_{b} \lambda_{b} \lambda_{b} \]  

(1)

where \( c \) is cohesion, \( q \) is surcharge and \( \gamma \) is the unit weight, \( N_{c}, N_{q} \) and \( N_{b} \) are bearing capacity factors, \( \lambda_{c}, \lambda_{q} \) and \( \lambda_{b} \) are shape factors, \( \lambda_{d}, \lambda_{q} \) and \( \lambda_{b} \) are embedment factors, and \( \lambda_{c}, \lambda_{q} \) and \( \lambda_{b} \) are inclination factors; \( B \) is the width of footings.

For eccentrically loaded strip footings, Meyerhof (1953) suggested the concept of effective width, \( B' \) to account for the reduction of vertical bearing capacity. In this concept, line of action for concentrated force \( V \) is assumed to be center line of the effect width, which is defined as \( B' = B - 2e \), as shown in Fig.1 (a). The eccentric load applied to footings can be equated to the combination of the centric load, \( V \) and the overturning moment, \( M \) as shown in Fig. 1 (b). Here, \( e \) is load eccentricity; \( V \) and \( M \) are considered along one unit length of continuous footing.

Further more,

\[ \frac{V}{V_{oc}} = (2 + \pi) \left( 1 - 2 \frac{e}{B} \right) \]  

(2)

\[ M = \pm 0.5 B \gamma V_{oc} \left( 1 - \frac{V}{V_{oc}} \right) \]  

(3)

where “+” and “-” refer to the case in which eccentric load is applied to the left or right side of the footing centre line, respectively; \( V_{oc} \) is the ultimate bearing capacity corresponding to vertical loading conditions.