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# EXTENDED ABSTRACT

# Bearing Capacity Factor Nc of Strip Footings on a Single Layer, using Integrated Limit Analysis with Finite Element

Farzin Khanebeigi, Kazem Badv*, Abbas Eslami Haghighat

*Department of Civil Engineering, Urmia University, Urmia, Iran*

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## 1. Introduction

The purpose of this paper is to investigate the influence of the bedrock and inhomogeneity of strength in depth, on bearing capacity of shallow strip footings. An upper bound limit analysis was applied which assumes a perfectly plastic soil model with an associated flow rule, using finite element and linear programming.

## 2. Methodology

### *2.1. Problem definition*

Soil profiles are often assumed to be homogeneous, but usually undrained shear strength of the normally consolidated clayey soils increases with depth. For small footings assuming $\varphi = 0$ and using the average value for $c_u$ can be acceptable, but for large footings changes in $c_u$ values with soil depth will have considerable effect on the bearing capacity of footings. Assumption that the cohesion is a function of depth, it could be expressed in terms of a linear relationship as below:

$$c_u = c_0 + (\rho b)z \tag{1}$$

in which, $C_0$ is the cohesion at ground surface, $b$ is the footing width and $\rho$ is the coefficient of cohesion corresponding to depth $(z)$ (Yang, 2016).

Also, the effect of bedrock on bearing capacity factor $N_c$ has been investigated by the dimensionless parameter $h/_b$ in which $h$, is the soil depth.

### *2.2. Formulation*

The objective function, restrictions, and adverbs to be applied to the objects by the linear programming are given below (Sloan and Kleeman, 1995).

$$\text{Minimize } C_1^T X_1 + C_2^T X_2 + C_3^T X_3 \tag{2}$$

$$\text{Subjected } A_{11}X_1 - A_{12}X_2 = B_1 \tag{3}$$

$$A_{21}X_1 - A_{23}X_3 = B_2 \tag{4}$$

$$A_{31}X_1 = B_3 \tag{5}$$

* Corresponding Author
*E-mail addresse:* khanebeygi@gmail.com (Farzin Khanebeigi), k.badv@urmia.ac.ir (Kazem Badv), a.eslami@urmia.ac.ir (Abbas Eslami Haghighat).

## 3. Results and discussion

### *3.1. Effect of rigid bedrock on the bearing capacity factor $N_c$*

If there is bedrock in the depth where the dimensionless ratio $(h/b)$ is smaller than the ratio $(Hcr\ /\ b)$, then the bedrock will affect the bounds of the failure mechanism and the ultimate bearing capacity. *Hcr* is the critical depth.

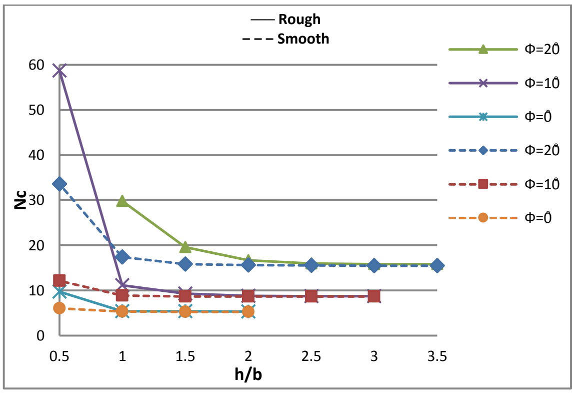


**Fig. 1.** Effect of rigid bedrock on the bearing capacity factor $N_c$

### *3.2. Effect of variable cohesion in depth on the bearing capacity factor $N_c$*

The effect of variable cohesion on the bearing capacity for various values of $\rho$ and $\varphi$ is shown in Fig. 2. From this figure it could be concluded that increasing cohesion in depth has an incremental effect on the bearing capacity. For example, in the case of smooth footings the bearing capacity *Nc* for $\rho = 3$ is about 2 times greater than that of constant cohesion.

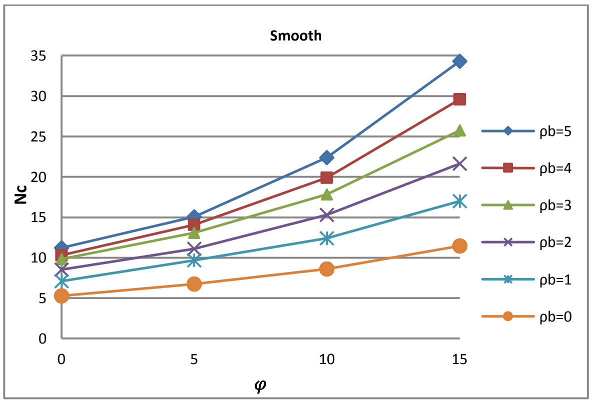


**Fig. 2.** Bearing capacity factor *Nc* against different values of $\rho$

### *3.3. Effect of simultaneous bedrock and cohesion variations on the bearing capacity*

In this section using the integration of the diagrams, the simultaneous impact of the bedrock and cohesion, are presented. The soil bearing capacity is expected to increase as soil depth decreases. The greater the distance from the critical depth or the less depth of the soil, results in the greater increase in the bearing capacity. But in the case of non-homogeneous soils with variable cohesion in depth, this applies at very low altitudes close to the surface. This conclusion is shown in Fig. 3.

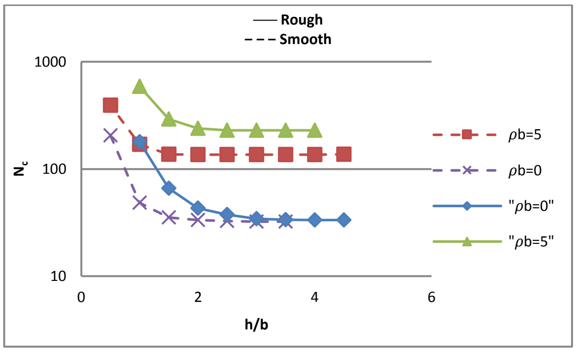


**Fig. 3.** The effect of bedrock on soil with variable cohesion

## 4. Conclusions

The factors affecting the bearing capacity $N_c$ were investigated by combining the upper bound theorem of limit analysis, finite element and linear programming. Two of these factors are the effect of bedrock and variable cohesion in depth.

The bedrock has a positive and incremental effect on the bearing capacity of the strip footings. For example, the value of $N_c$ for smooth strip footings with bedrock underlying a soil having $\varphi = 40$ and $h/_b = 1.5$ is approximately 1.5 times greater than the bearing capacity of $N_c$ in the condition without bedrock.

Increasing cohesion in depth has an incremental effect on bearing capacity. For example, in the case of smooth footings, the bearing capacity factor $N_c$ for $\rho = 3$ is about 2 times greater than that of constant cohesion in depth. This number for rough footings is about 3 times greater than the soil with constant cohesion in depth.

Considering the simultaneous bedrock and variable cohesion with depth, it can be concluded that having bedrock in soil with variable cohesion, causes the stability of $N_c$ value to a depth which is close to the ground surface.

## 5. References

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