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Effects of Joint Spacing on Static Bearing Capacity of Rock Foundations in the case of Punching Failure

S. M. Imani[1*], A. Fahimifar[2], M. Sharifzadeh[3]

1- Ph.D. Student, Department of Civil & Environmental Engineering, Amirkabir University of Technology
2- Professor, Department of Civil & Environmental Engineering, Amirkabir University of Technology
3- Associate Professor, Department of Mining & Metallurgical Engineering, Amirkabir University of Technology

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ABSTRACT

In this paper, using distinct element method, static bearing capacity of rock foundations containing one, two or three joint sets is investigated in the case of punching failure. The effect of joint spacing is incorporated in the analyses using a dimensionless factor, named spacing ratio (SR). Different values for SR are selected and variation of bearing capacity versus SR is monitored. Then, the magnitude of SR in which the bearing capacity is not changed significantly, is determined. The findings show that for SR<30, increasing SR results in decreasing bearing capacity, while for SR>30, joint spacing does not affect bearing capacity, significantly. Hence, SR=30 can be used as a criterion for analysis of rock foundations either as an equivalent continuum or a discontinuous medium. Using this criterion, it will tend to greatly reduce the time required for bearing capacity analysis of rock foundations.

KEYWORDS

Bearing Capacity, Rock Foundation, Punching Failure, Spacing, Direct Approach.

* Corresponding Author, Email: imani@aut.ac.ir

1- INTRODUCTION

Depending on the failure mode of rock foundations, spacing of joints have different influences on the bearing capacity. In practice, two main failure modes may occur which are named as general shear failure and punching shear failure. The latter can be attributed as the failure due to an excessive deformation. Most of the methods for determining rock bearing capacities are based on the general shear failure mode, and the methods proposed by Imani et al. (2012), Merifield et al. (2006), Saada et al. (2008) and Yang and Yin (2005) are among them .

In this paper, the effect of joint spacing on the bearing capacity of the rock foundations in the punching failure mode is investigated. The distinct element method (DEM) was used to investigate the effect of joint spacing on the bearing capacity. In this regard, the concept of "spacing ratio" (*SR*), that initially proposed by Serrano and Olalla (1996), was used to introduce the joint spacing into the discontinuum numerical models. The non-dimensional parameter, *SR*, is expressed as follows:

$$SR = B\sum_{i=1}^{n}\frac{1}{S_i} \tag{1}$$

Where, B is the footing width, S_i is the spacing of the i^{th} joint set and n is the number of joint sets.

Using load-settlement curve obtained from the numerical analyses, the ultimate bearing capacity was obtained for different magnitudes of *SR* (from 3 to 50), and the particular *SR*, in which the rate of variation of the bearing capacity becomes negligible, was selected as the limit of joint spacing effectiveness. Finally, the sensitivity analyses were performed to show the effects of rock mass strength parameters on the limiting value of SR proposed in the present research.

2- METHODOLOGY

Most of the existing analytical methods for determining ultimate bearing capacity of rock foundations are based on the general shear failure of the rock mass. Therefore, they seem not to be proper for the case of a failure induced by excessive deformation of the mass. In such cases, load-settlement curve is a popular tool in estimating critical load. This curve can be obtained from the loading tests in the field or using numerical methods, which the latter was used in this study by applying the distinct element method. The stress corresponding to a settlement equals to 10% of the foundation width is often defined as the bearing capacity (the 0.1*B* method). Jointed rock foundations containing two orthogonal joint sets were considered for dealing with the problem of failure due to an excessive deformation. Fig. 1 shows the general configuration of some of the constructed models.

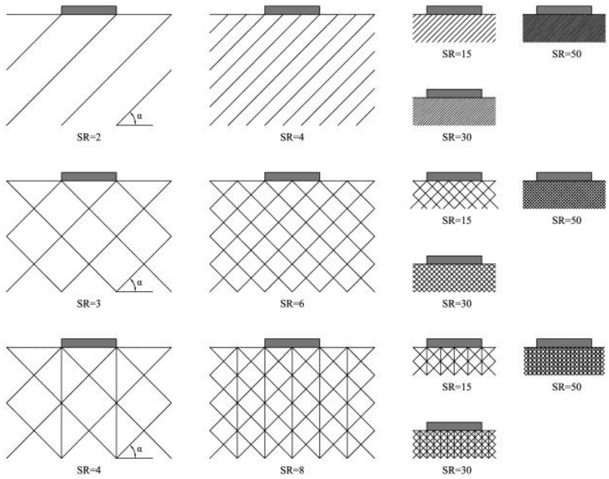

FIG 1. GENERAL CONFIGURATION OF SOME OF THE CONSTRUCTED MODELS

3- RESULTS

In the constructed numerical models, it was assumed that $\phi_i = \phi_j = 35°$, joint normal and shear stiffnesses (K_n and K_s, respectively) are equal to 100 GPa/m, c_i=20 MPa and c_j=2 MPa. Fig. 2 shows the variations of the q_u/c_i ratio obtained from the 0.1*B* method, versus *SR* for the value of α equals to 45° and for two joint sets. According to the figure, for *SR*<30, increasing the *SR* results in decreasing the bearing capacity, but for *SR*>30, the joint spacing does not affect the bearing capacity, significantly. Hence, *SR*=30 can be taken into account as the approximate limit for the influence of jointing on the bearing capacity and is named in this study as the critical spacing ratio (SR_{cr}).

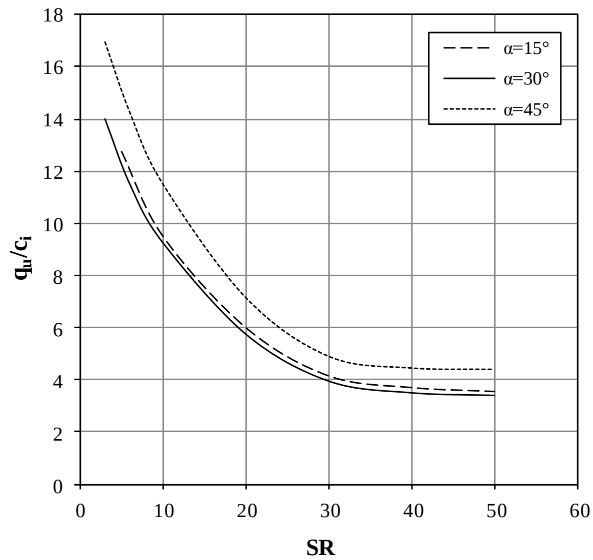

FIG 2. VARIATION OF q_u/c_i WITH *SR* FOR TWO JOINT SETS

The results obtained through the distinct element method are highly dependent on the selected rock parameters. For considering the effect of the intact rock and the joint set properties on the SR_{cr}, the sensitivity analyses were performed. Different values for the intact rock and the joint sets cohesion and friction angle, the

settlement magnitude at critical load and the joint normal and shear stiffness were considered. The obtained results reveal that the SR_{cr}=30, proposed in this research, does not change with any changes in the above mentioned properties. Because of the large number of models, the results of the sensitivity analyses on the cohesion ratio (c_j/c_i), for the case of α=30°, is only presented here.
Fig. 3 presents the q_u/c_i versus *SR* for c_j/c_i =0.1, 0.2 and 0.3. Keeping c_i unchanged as assumed previously (c_i=20 MPa), the other properties were assumed as previous.

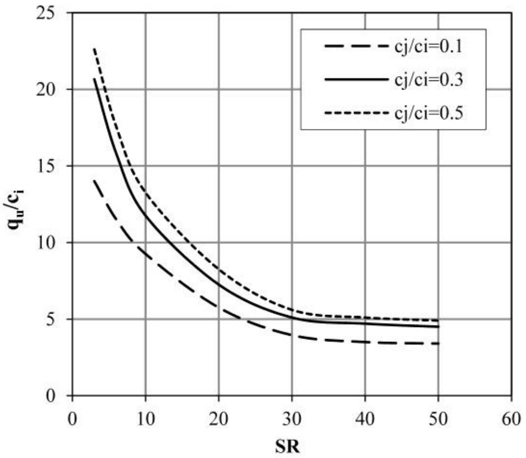

FIG 3. VARIATION OF q_u/c_i VERSUS *SR* FOR c_j/c_i=0.1, 0.3 AND 0.5

4- CONCLUSIONS

The results obtained from this research show that for *SR*<30, increasing the *SR* results in decreasing the bearing capacity, but for *SR*>30, the joint spacing does not affect the bearing capacity significantly.
Since the failure due to an excessive deformation may occur prior to the general shear failure, determining the ultimate bearing capacity of the rock foundations, only by using the equations based on the general shear failure of rock foundation, may lead to unrealistic results.

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