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The influence of the void shape in the bearing capacity of rock mass with a superficial void

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Introduction

The existence of an underground void (associated with a cave, tunnel or mining works) changes the mechanical behavior of a rock mass. Therefore, it is expected that when the void is located close to the surface the bearing capacity of a shallow foundation on a rock mass is reduced. However, in the field of rock mechanics, few studies quantify this reduction in a systematic way.

The present study proposes a chart that allow estimating the reduction of bearing capacity due to the existence of a superficial void in a rock mass. It is contemplated the influence of different shapes and size of the void in relation to the foundation.

The results demonstrate that the critical depth where the cavity no longer influences the bearing capacity varies considerably depending on the geometric variables (size, shape and location of the void).

In addition, it is observed that the relation between the bearing capacity obtained considering the rock mass with and without void is not affected by the geotechnical parameters of the H&B failure criterion.

Methodology

Numerical calculations were carried out using 2D models in the finite difference method employing the commercial code FLAC. The simulations applied the plane strain condition (strip footing) with a symmetrical model, where only half of the strip footing is represented (Fig. 1). In all simulations the self-weight of rock mass is considered, the associative flow-rule and the rough interface at the base of the foundation are adopted. The Modified Hoek-Brown constitutive model was used to model the rock mass.

In the numerical calculations the model is simplified by adopting a footing as a load (velocity increments) applied directly on the ground surface.

Eighteen types of rock mass were generated, with the values listed in Table 1.

This study included a great range of shapes, locations and sizes of the void (see Fig. 2). Three different void sizes and locations of the void are considered (Table 2), however, it is emphasized the adoption of other values for the foundation width (eccentricity/slenderness) is only a change of scale. Vertically the depth of the void is varied from very shallow (R/B = 0.6) to the depth at which the void no more affects the bearing capacity

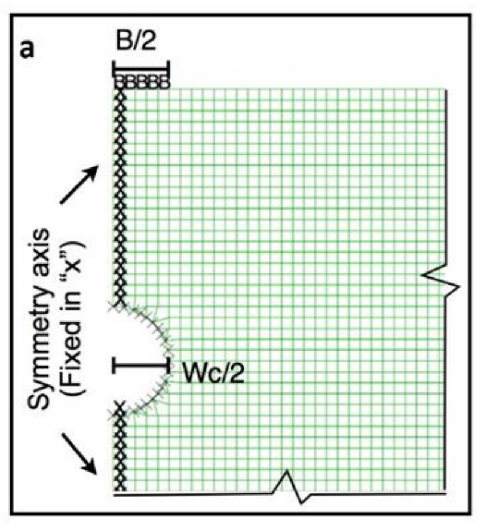

Figure 1. 2D model used in the calculation through FDM.

Table 1: Summary of the geotechnical parameters adopted.

m_i	GSI	UCS (MPa)
5	10	20
12	50	60
25	85	

Table 2: Summary of the geometrical parameters adopted.

W_c (m)	W_h (m)	W_v (m)
0.5	0.5	1
1	1	2
2	2	4

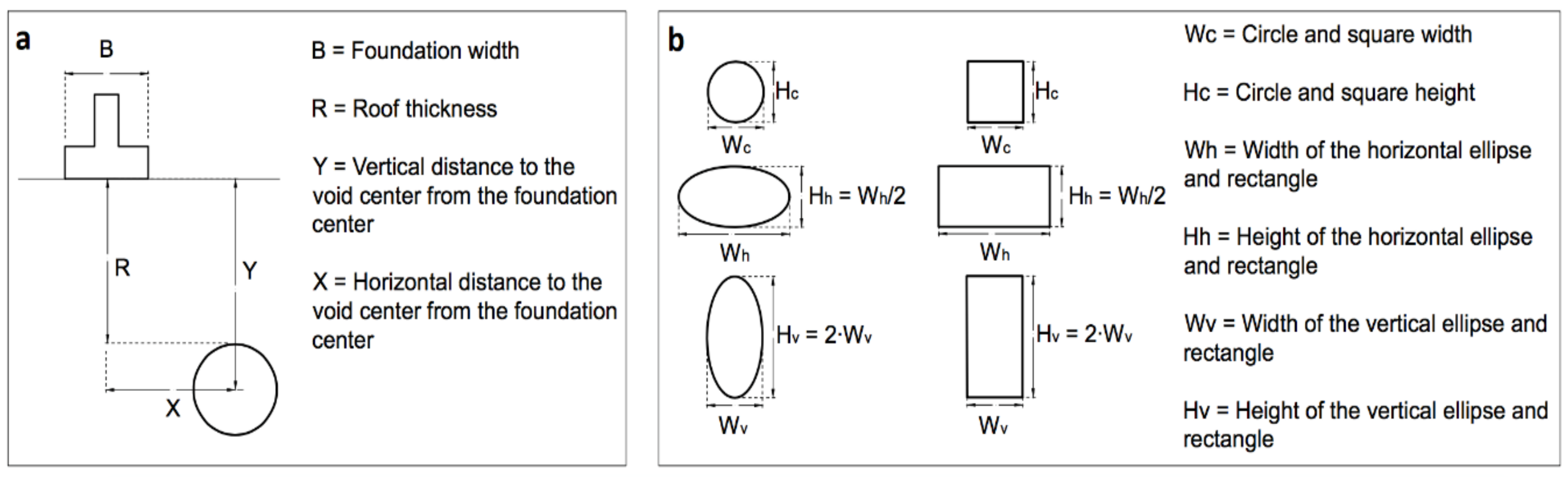

Figure 2. Geometry of the model, representing a footing on the rock mass with one void. (a) Model geometry; (b) Void geometry.

Results

The correlation coefficient V_F (void factor) is proposed, which is defined as the value that must be multiplied to the bearing capacity of rock mass without a void (P_h), to obtain the bearing capacity of the rock mass with the same geotechnical characteristics but with a void (P_{hv}).

$$V_F = \frac{P_{hv}}{P_h}$$

The analyses were carried out adopting the centered load (X = 0).

The charts in Fig. 3 allows the estimation of the reduction of the bearing capacity of a rock mass due to the presence of a rounded or rectangular cavity in a generic way (independent of the slenderness of the cavity).

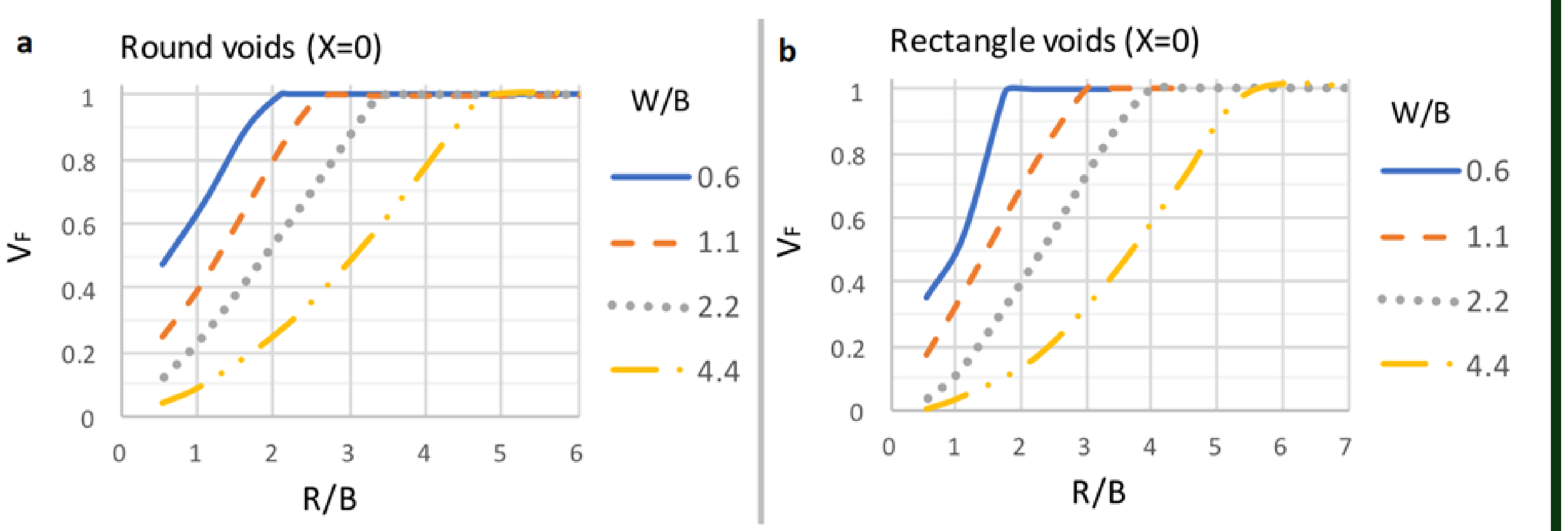

Figure 3. V_F for round and rectangular voids and X=0. (a) Round voids; (b) Rectangle voids

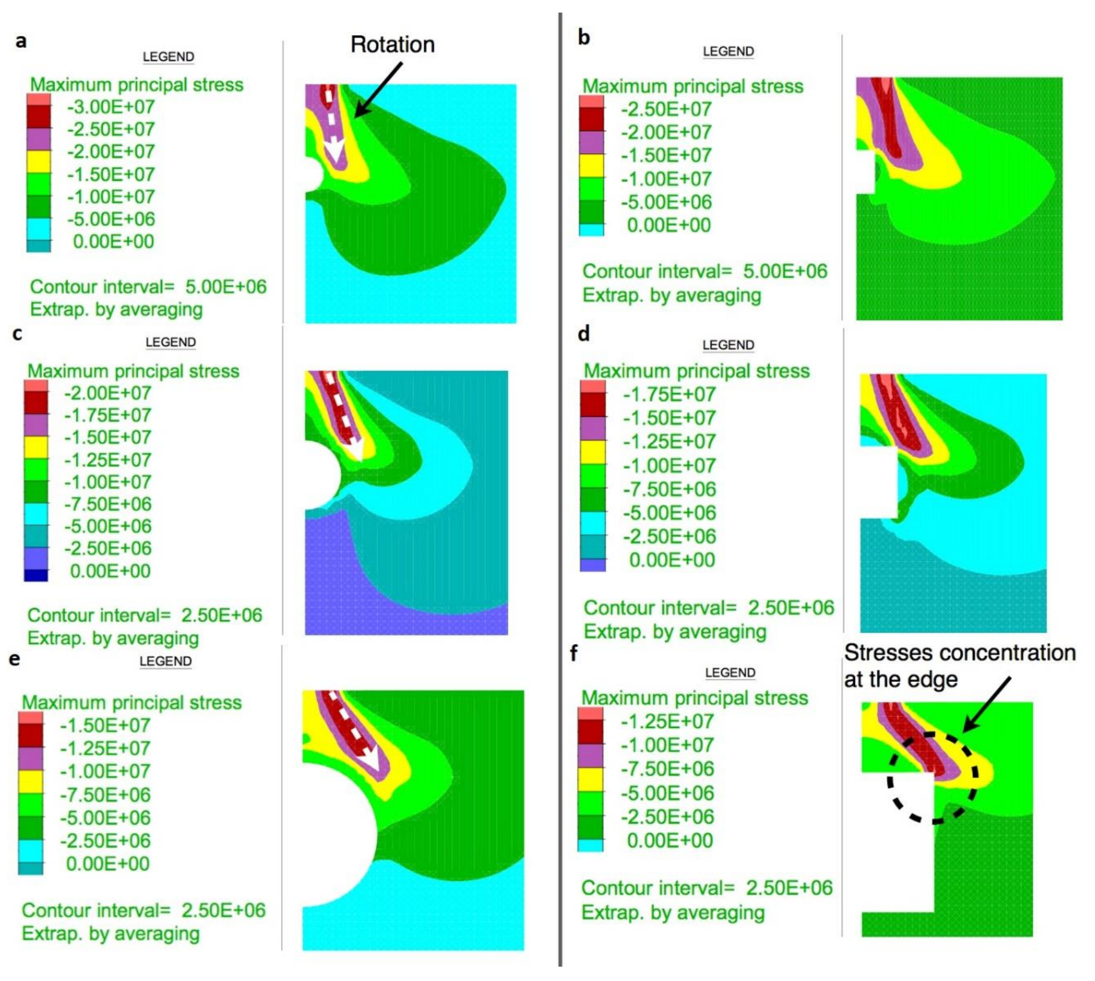

Figure 4. The variation of the principal stress obtained by FDM under the foundation (R/B = 1.1). (a) Round void, Wc/B = 0.6; (b) Square void, Wc/B = 0.6; (c) Round void, Wc/B = 1.1; (d) Square void, Wc/B = 1.1; (e) Round void, Wc/B = 2.2; (f) Square void, Wc/B = 2.2

Fig. 4 shows the graphic output of the maximum principal stress, where it can be observed that if the void width varies (keeping constant *B* and *R*) the stress distributions changes. It is noted that the stresses directions rotate horizontally to deflect the cavity, being biggest the rotation, the wider is the void.

It is also observed a concentration of stress in the upper corner of a square void, which explains why V_F values are smaller in cases associated with rectangular voids in comparison with voids with rounded edges.

Conclusion

It is observed that the shape of the cavity, rectangular or rounded, interferes in the V_F value. Thus, the rounded voids allow a better stress distribution in the rock mass. The rounded cavities decrease less the bearing capacity of a rock mass compared to a cavity of similar width but with straight edges. It is also noted that the greater the W/B (void width / foundation width) ratio the greater is the influence of the shape on the value of V_F.

The graphic output of maximum horizontal and vertical displacements are consistent with the results obtained. Regarding the void shape it is noted that stress is concentrated in the upper corner of a square void, resulting in a weak point that does not occur in the round void. It is also observed that the stress rotates towards the horizontal direction to deflect the cavity, being bigger for wider voids.

Finally, a chart is proposed that allows the estimation of the value of V_F considering a centered load

Acknowledgments

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