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Study on the effect of joint roughness for deformation modulus of rock masses based on numerical tests

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ABSTRACT. *The deformation modulus of a rock mass is among the parameters that can best represent the mechanical behavior of a rock mass. To study the effect of joint roughness on deformation modulus of rock masses, several numerical tests are conducted in this article.The following conclusions can be drawn from the results. (a) the value of JRC(joint roughness coefficient) can affect the deformation modulus; (b) when JRC is less than eleven, the deformation modulus increases with the increase of JRC, and decreases with the decrease of JRC when JRC is greater than eleven; and (c) when JRC is equal to zero (flat joints), the deformation modulus is smaller than others.*

KEYWORDS: *rock mass, deformation modulus, numerical tests, joint roughness coefficient*

1. Introduction

The deformation modulus of a rock mass is among the parameters that can best represent the mechanical behavior of a rock mass [1]. Therefore, many scholars have studied the deformation modulus. The research method of deformation modulus of rock masses can be divided into two parts: in situ methods and indirect test methods.

The in situ test methods are considered to be expensive and difficult to conduct. In contrast to in situ tests, indirect methods are simple and economical. Indirect methods includes empirical methods, analytical methods and numerical tests. The

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empirical method uses the established relationship between rock mass index and deformation modulus to study the local deformation modulus. However, there are many different empirical formulas, which means that different deformation modulus can be obtained for the same rock mass. The deformation modulus also can be studies by analytical methods [2-3], but the joints in their study were considered to be flat joints, which is different from the actual joint [4-5].

Fortunately, the numerical tests can be used to study the deformation modulus with joint roughness considered. Therefore, this article aims to study the effect of joint roughness on deformation modulus of rock masses by numerical tests.

2. Methodology

2.1 Establishment of joint model with different roughness

Based on research for fractal dimension and *JRC* [6], joints with different roughness are established in this paper. The joint surface state with different roughness is shown in Fig. 1, according to Eqs. (1)-(2).

$$D = \lg 4 / \lg\{2[1+\cos(\arctan(2h/L))\} \quad (1)$$

$$JRC = 85.2671(D-1)^{0.5679} \quad (2)$$

Where D is the fractal dimension, h is average height of the joint, L is average base length of the joints, and JRC is the joint roughness coefficient.

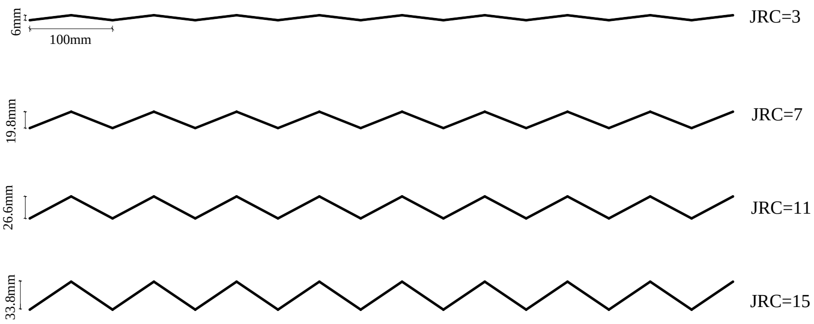

Figure. 1 Joints with different roughness

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2.2 Establishment of numerical models

In order to study the deformation modulus of rock masses with different roughness joints, five 5 m × 5 m discrete fracture network (DFN) models were generated by Monte Carlo Simulations in Matlab (Table 1), and the rock masses with flat joints and rough joints with *JRC* of seven are shown in Fig. 2. By applying a unidirectional load on the upper and lower boundaries and recording the data of stress and strain, the deformation modulus can be obtained.

Table 1 Geometric parameters of the joints of models

Group	*JRC*	Trace length			Joint position distribution	dip angle
		Expected value	Standard deviation	Distribution		
1	0	1m	0.1	Normal	Uniform	30°
2	3					
3	7					
4	11					
5	15					

Table 2 Mechanical parameters of the joints and intact rock

k_n(GPa/m)	k_s(GPa/m)	E_r(GPa)	G_r(GPa)	c_r(MPa)	φ_r(°)
20	15	50	20	20	40

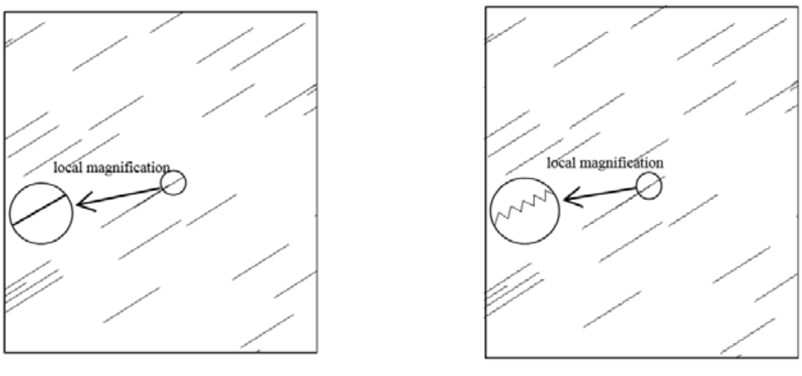

Figure. 2 The rock masses with flat joints and rough joints with JRC of seven.

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3. Results and analysis

For Group 1-5, which have different values of *JRC*, the deformation modulus obtained are shown in Fig. 3. The result in Fig. 3 shows that (a) the value of *JRC* can affect the deformation modulus; (b) when *JRC* is less than eleven, the deformation modulus increases with the increase of *JRC*, and decreases with the decrease of *JRC* when *JRC* is greater than eleven; and (c) when *JRC* is equal to zero (flat joints), the deformation modulus is smaller than others. The reason is that, *JRC* increases the stiffness of the joint, so it makes the joint deformation more difficult, and the deformation modulus increasing. When *JRC* increase to a certain extent, the critical stress required to shear the bulge will decrease, and the bulge is easier to be sheared. When the bulge is sheared, *JRC* will only be reduced to a certain extent, because not all bulges are completely sheared. This explains why the deformation modulus decreases to a certain extent when *JRC* is equal to fifteen, but it is still greater than that when *JRC* is equal to 0 (flat joint).

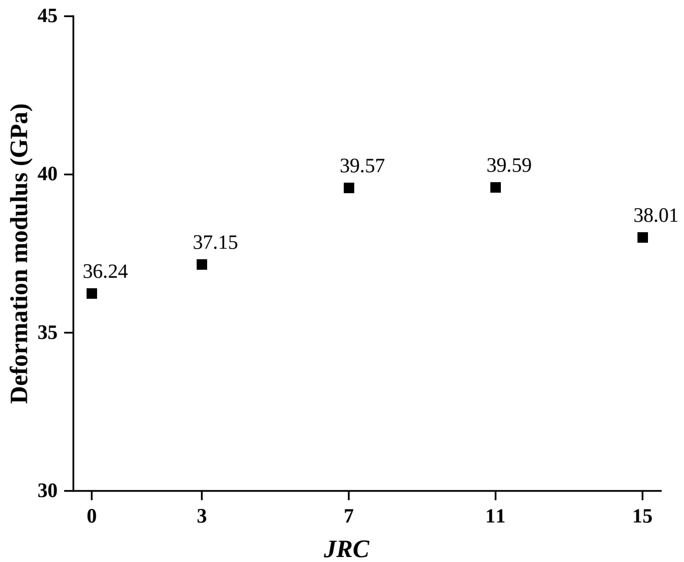

Figure. 3 Deformation modulus of rock masses with different roughness joints

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4. Conclusion

By conducting the numerical test of the rock mass without the same roughness joint, we can know that (a) when *JRC* is less than eleven, the deformation modulus increases with the increase of *JRC*, and decreases with the decrease of *JRC* when it is greater than eleven; and (b) when *JRC* is equal to zero (flat joints), the deformation modulus is smaller than others. In general, *JRC* has a positive effect on the deformation modulus, Compared with the flat joint.

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