# Discussion on Joint Surface Roughness Coefficient evaluated through the root mean square method

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## 1. INTRODUCTION

Joint roughness is one of the important parameters to evaluate the mechanical and the hydro mechanical behavior of rock joints. To describe the joint surface, the joint roughness coefficient (*JRC*) has been introduced, Barton. (1973). In the definition of *JRC*, the coefficient has a strong relationship with the peak dilation angle and the value can be calculated by the backward analytical method from the tilt test or the direct shear test. Another approach to predicting the *JRC* value is the root mean square ($Z_2$) method, Tse & Cruden. (1979). It establishes the relationship between the joint surface and the shear strength based on the mean inclination angle which obtained from the profiling data. However, some research indicated that $Z_2$ method only considers the mean inclination angle and neglects the influence of the distribution of the inclination angle and amplitudes, Guangcheng et al. (2014). Thus, this method may misestimate *JRC* values.

In this study, we compared two kinds of joint surfaces which have same mean inclination angle and different amplitudes. The *JRC* values are calculated by the $Z_2$ method and the results are verified by the backward analytical method.

## 2. SHEAR MECHANICAL MODEL

In this experiment, instead of the tilt test, the shear mechanical model is utilized to explore the shear behavior of rock joints. This model shows good agreement with the result of the direct shear test in mortar specimens, Kishida & Tsuno. (2001). It assumes that shear behavior of rock joints is governed by some contacted asperities. When the concentrated stress is larger than the uniaxial compressive strength on the contacted points, those larger angle asperities are shaved. Then, the asperities with smaller angles gradually come into contact and the contacted asperities and contacted area increase. Until the concentrated stress become smaller than the uniaxial compressive stress, the specimen slides along those contact asperities. The contacted asperities are extracted and shown in **Fig. 1**.

The specimens are set as the rectangular mortar solid with a cross section of 120 mm × 80 mm (80 mm in shear direction) and a height of 120 mm. The material properties are shown in table 1.

**Fig. 2** shows two kinds of joint surfaces. It is assumed that the inclination angles ($\theta$) of two joint surfaces are 15 degrees but the Joint *a* has one amplitude and Joint *b* has four amplitudes. The profiled data of two surfaces are used to calculate the $Z_2$ and simulate the shear behavior by shear mechanical model.

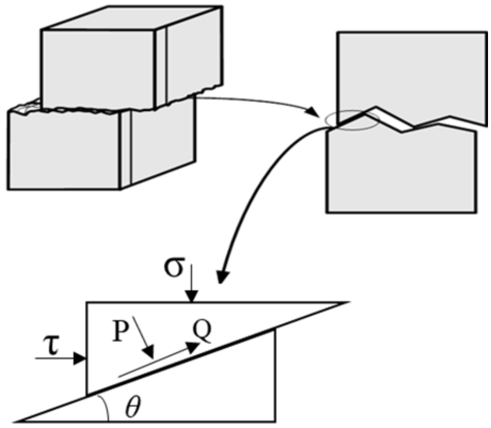


**Fig. 1** Stress on the contacted asperities

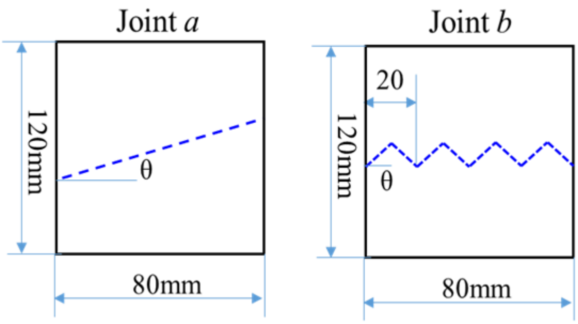


**Fig. 2** Two kinds of joint surfaces

**Table 1** Material properties of the specimens

| Case | Material | Uniaxial Strength | Basic friction angle | Confining stress |
|---|---|---|---|---|
| Joint *a*<br>Joint *b* | mortar | 22.44 MPa | 34.0 | 0.5 MPa<br>1.0 MPa<br>3.0 MPa<br>7.0 MPa |

## 3. EXPERIMENTAL RESULTS

### 3.1 *JRC* values calculated by $Z_2$

Root Mean Square method is one of the most useful methods to predicting the *JRC* values before the direct shear experiment. The formulation of $Z_2$ and the relation between $Z_2$ and *JRC*s are given as follows:

$$Z_2 = \sqrt{\frac{1}{L}\int_{x=0}^{x=L}\left(\frac{dy}{dx}\right)^2 dx} \tag{1}$$

$$JRC = 60.32Z_2 - 4.51 \tag{2}$$

where $Z_2$ is the Root Mean Square, $L$ is the length of the profiling joint surface, $x$ is the distance between two adjacent asperity points, $y$ is the height of the surface points. Here, Xianbin. et al (1991) proposed that $Z_2$ is sensitive to the sampling interval of profiling data. In

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this experiment, the surface asperity points are discrete as 0.25 mm and we use the Eq. (2) to express the relation between *JRC* and $Z_2$.

The *JRC* values of Joint *a* and *b* have the same value due to the mean inclination angle of them keeps the same.

$$JRC_a = JRC_b = 11.65 \tag{3}$$

### 3.2 *JRC* values calculated by the back analysis

According to the formula Eq. (3) proposed by Barton. The *JRC* values can be obtained by back analysis and the relation is shown as Eqs. (4) and (5):

$$\tau = \sigma_n \tan\left[JRC\log_{10}\left(\frac{JCS}{\sigma_n}\right) + \Phi_b\right] \tag{4}$$

$$JRC = \frac{\tan^{-1}\left(\tau/\sigma_n\right) - \varphi_b}{\log_{10}\left(JCS/\sigma_n\right)} \tag{5}$$

where $\tau$, $\sigma_n$, $\varphi_b$, *JCS*, and $\tan^{-1}\left(\tau/\sigma_n\right)$ are the shear stress, the normal stress, the basic friction angle, the joint wall compressive strength and the peak dilation angle respectively.

**Fig.3** shows the shear stress-shear displacement relations of the Joint *a* and *b* under different normal stress respectively. The peak shear stress can be observed in each normal stress and the shear stress increased with the confining load raised.

From the **Fig.4**, it is described the relation between normal stress and peak shear strength. It can be found out that the ratio between the peak shear strength and the normal stress are almost at the same value. The *JRC* values calculated by the simulation result of the shear mechanical model are shown as follow:

$$JRC_a = JRC_b = 15 \tag{6}$$

## 4. CONCLUSIONS

By the backward analytical method, the same *JRC*s are found on the regular joint surfaces which have the same mean inclination angle and different amplitudes. These values are larger than the results of $Z_2$ method. Therefore, the *JRC* values predicted by $Z_2$ method may underestimate the shear strength. Moreover, the results calculated by two approaches indicate that two surfaces have the same roughness asperity. However, the roughness of two regular surfaces is different in fact. In the future, the method of accurately estimating the roughness should be more discussed.

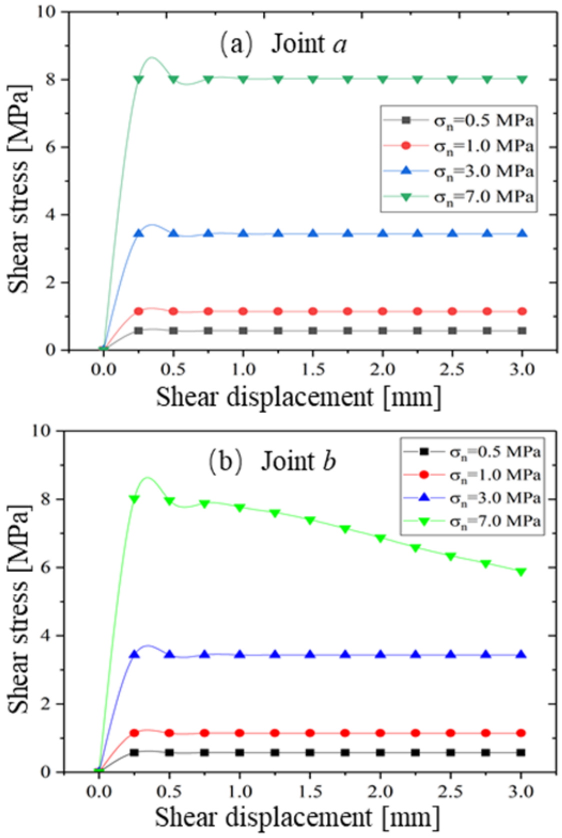


**Fig. 3** The shear stress-shear displacement relations of the Join *a* and *b*

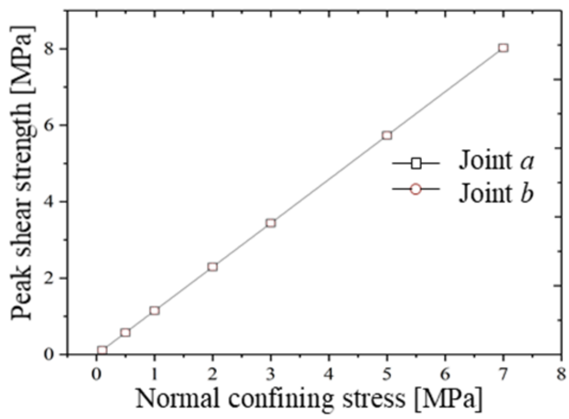


**Fig. 4** The relation between normal stress and peak shear strength

## REFERENCES

1) Barton, N.: Review of a new shear strength criterion for rock joints. *Eng Geol*; Vol.7: 1973, pp. 287–332.
2) Tse, R., & Cruden, D. M. Estimating joint roughness coefficients. *International Journal of Rock Mechanics and Mining Sciences & Geomechnics*, 16(5), 1979, pp. 303–307.
3) Guangcheng, Z., Murat, K., Huiming, T., and Yunfeng, G.: A new method estimating the 2D Joint Roughness Coefficient for discontinuity surfaces in rock masses, *International Journal of Rock Mechanics & Mining Sciences,* Vol.72, 2014, pp. 191-198.
4) Kishida, K., and Tsuno, K.: The modeling of the shear behavior of rock joints in consideration of the material friction and the joint surface roughness. *J Geotech Eng JSCE*, 680/III-55, 2001, pp. 245–61.
5) Xianbin, Y., & Vayssade, B. Joint profiles and their roughness parameters. *International Journal of Rock Mechanics and Mining Sciences & Geomechnics*, 28(4), 1991, pp. 333–336.