Influence of sampling resolution on joint roughness evaluation employed two different methods

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1. INTRODUCTION

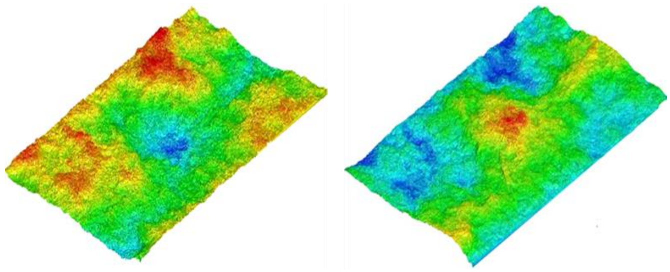
The joint surface roughness significantly influences the mechanical and hydro-mechanical behaviour of discontinuous rock mass. The most widely used characteristic to predict the joint roughness coefficient (*JRC*) is the root mean square first derivation (Z_2) which can be calculated from the profiled surface information, Barton, (1973) and Tse and Cruden, (1979). Thus, it is necessary to accurately record the geometrical surface information by the appropriate measuring instruments. Although diverse instruments have been used in previous studies, the influences of precisions and resolutions during roughness profiling are not sufficiently considered before. Moreover, the selection of sampling interval being used to map the rock joint surface is not yet fully explicit in past research.

The present study adopted both low- and high-resolution sampling machines, that are laser scanner and light projection, to profile the entire granite joint surfaces. We estimated the *JRC* values from two kinds of profiled data and compared them with the definitional *JRC*. Then, we discussed the influences of profiling precisions and resolutions on *JRC* evaluation on the initial joint surface and the sheared joint surface.

2. METHODOLOGY

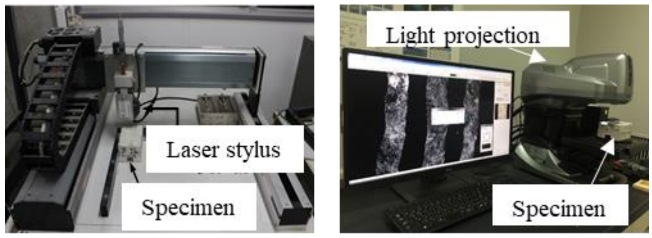
In this study, granite was sampled from an actual tunnel located at Toyota, Japan. A thoroughgoing fracture was created at the centre of rock block by Brazilian tests and was approximately aligned on the horizontal plane. Then a rectangular specimen was formed with a cross-section of 120 mm × 80 mm and a height of 120 mm. The contour maps of specimens are shown in **Fig.1**. The material properties of the granite specimen are given in Table 1.

Two kinds of remote no-contact techniques were employed to measure and characterize the roughness of rock joints. One of the widely used instruments is the laser scanner, which can calculate the travel distance of the pulsed beam to record the surface geometrical information. The granite joint surface was measured with the interval of 0.25 mm by the laser scanner. Some errors were caused by the diffuse reflection from dark and bright minerals on surfaces. To calibrate these error points, the digital data were corrected by using the average height values of neighbouring points. Another technique for mapping the surface is the light projection (or optical cutting method) which has extremely high precision and excellent repeatability. The sampling interval could be accurate to 0.025 mm for the objective surfaces. Contrast with the laser scanner, the light projection has high precision and high resolution. **Fig.2** shows two kinds of profiling techniques.



(a) (b)

Fig. 1 Contour map of the joint surface roughness: (a) lower surface and (b) upper surface



(a) (b)

Fig. 2 Two kinds of profiling techniques: (a) laser scanner and (b) light projection

Table 1 Material properties of the granite specimen

Material	Uniaxial Strength	Basic friction angle	Normal stiffness
Granite	140.31 MPa	38.8	60.85 MPa

3. PROFILING RESULTS

3.1 Distribution of Z_2 values

The root mean square first derivation (Z_2) is related to the roughness slope, which can be used to predict the friction of the surface, Myers. (1962). This statistical characteristic is obtained by calculating the cumulative inclination of surface roughness along one profiling line. The formulation is expressed as Eq. (1).

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

where L is the length of the profiled joint surface, x is the distance between two adjacent asperity points, y is the height of the surface points.

The *JRC* value is usually obtained by calculating Z_2 value of one profiled line on the joint surface. Thus, it is essential to investigate the distribution of all Z_2 values on the entire surface. Here, the joint surface was profiled by the laser scanner and the light projection with the sampling distance of 0.25 mm. Meanwhile, the effects of precision of two measuring instruments were discussed. The distribution of Z_2 values with the sampling interval of 0.25 mm is shown in **Fig.3**.

Keywords: joint roughness, root mean square, initial surface, sheared surface, profiling resolution
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In **Fig.3**, there exists dispersion among the Z_2 values of the entire joint surface. In addition, using the laser scanner which has relatively low precision, the dispersion of Z_2 values is more apparent in **Fig.3 (a)**. Thus, rather than one arbitrary Z_2 value, the mean Z_2 value of all profiles is more accurate to represent the joint roughness, which can take into consideration the morphology of the entire joint surface. Moreover, the mean Z_2 values obtained from two instruments are close. It is also helpful to remove the bias from using measurement instruments with different precision.

3.2 *JRC* evaluation

JRC values can be calculated from Z_2 characteristic using some empirical relationships. Yu and Vayssade, (1991) proposed several linear relationships responding with different sampling intervals. These relationships are given by Eqs. (2), (3), (4):

$$JRC = 60.32Z_2\text{-}4.51 \ (SI\text{=}0.25 \text{ mm}) \quad (2)$$
$$JRC = 61.79Z_2\text{-}3.47 \ (SI\text{=}0.5 \text{ mm}) \quad (3)$$
$$JRC = 64.22Z_2\text{-}2.31 \ (SI\text{=}1.0 \text{ mm}) \quad (4)$$

where *SI* is the sampling interval. The evaluated *JRC* values are compared with the definitional *JRC* that are calculated by Barton-Bandies model, Barton and Bandis, (1990). The results are shown in **Fig.4**.

In **Fig.4**, it is confirmed that the evaluated *JRC* values decrease with the increase of sampling intervals at the interval range from 0.25 mm to 1.0 mm. For the initial joint surface, the estimated *JRC* value is close to the definitional *JRC* value with the sampling interval of 1.0 mm. For the sheared joint surfaces, the profiling data from light projection with high resolution could demonstrate the reduction of *JRC* after the shear process. However, the Z_2 method overestimates the *JRC* values in sheared surface.

4. CONCLUSIONS

Contrast with the laser scanner, the light projection with high resolution and high precision could provide more even Z_2 distribution of the entire joint surface and demonstrate the alteration of surface roughness after shear process. Meanwhile, the sophisticated measurement is helpful to accurately profile the joint surface and make reasonable *JRC* evaluation. In addition, the *JRC* estimated from the mean Z_2 characteristic with 1.0 mm sampling interval shows a good agreement with the definitional *JRC* value in the initial surface. However, this Z_2 method in this study overestimates the *JRC* values of joint surface which suffered the shear process. In the future, it is necessary to consider other geometrical characteristics to evaluate the roughness of sheared surfaces accurately.

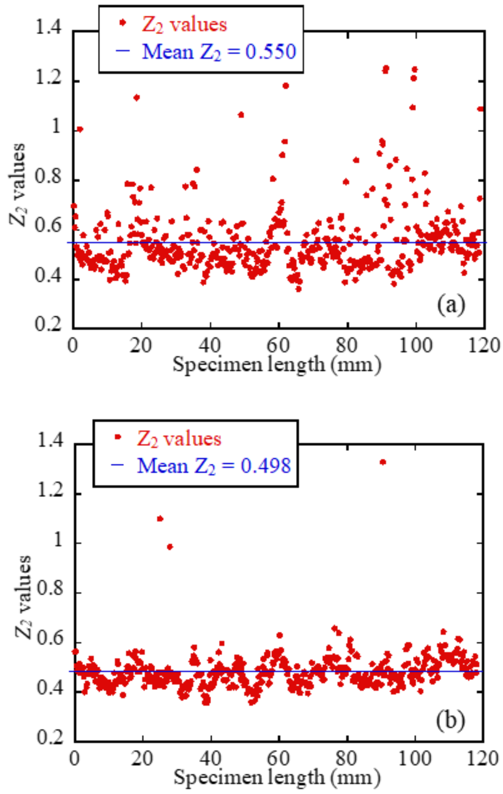

Fig. 3 Distribution of Z_2 values: (a) data from laser scanner and (b) data from light projection

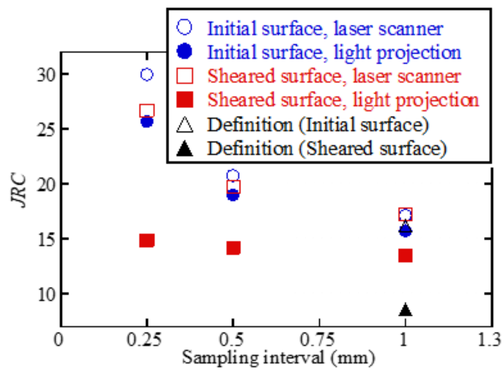

Fig. 4 Evaluated *JRC* and definitional *JRC* in initial surface and sheared surface

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