Large Rock Reliefs and Their 3D Reconstructions

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Large Rock Reliefs and Their 3D Reconstructions

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Abstract. Rock reliefs are used for assessing joint rock coefficients that serve in geotechnical engineering for computing shear strength of rock joints. The three-dimensional reliefs of small rock joints amounting to several centimetres may be digitally reconstructed in laboratories but large joints whose sizes reach several meters have to be reconstructed in terrains and require a specially adapted technique for three-dimensional reconstruction. This contribution describes one of the devices capable of performing digital reconstructions in terrains. This device has been developed in our laboratory on the basis of affordable components.

1. Introduction

Barton, Choubey and Bandis [1 - 3] introduced a model for computing shear strength τ of rock joints in the following form

$$\tau = \sigma_n \, tg\left[JRC \cdot \log\left(\frac{JCS}{\sigma_n} \right) + \phi_r + i_u \right] \tag{1}$$

where σ_n is normal effective stress, *JCS* represents effective joint wall compressive strength, *JRC* joint rock coefficient, ϕ_r basic friction angle (material constant) and i_u is the inclination angle of rock asperities that is related to large scale undulation of bedding plane (second order asperities). The term i_u for second order asperities was invented by Bandis [3]. Soon after the *JRC* concept had been published, various authors [4-6] attempted to find a functional form for *JRC*.

The most problematic term in Eq. (3) is the joint rock coefficient *JRC*. Its value is usually determined by means of comparison of the investigated rock reliefs with the database reliefs of known *JRC* values. The first step for the computer controlled comparison is to form the digital three-dimensional (3D) relief of the investigated rock sample. The present contribution discusses an unconventional procedure for creating 3D digital reliefs and describes a device capable of digitizing large reliefs in terrains.

2. Digitizing 3D procedure

There are various expensive commercial devices for digitizing solid surfaces but we decided to develop a new prototype on the basis of affordable components. The device was constructed in such a way to serve both in laboratories and terrains, i.e. for digitizing both the small and large reliefs.

The philosophy of the device has been based on the sectional technique. This technique reconstructs the 3D reliefs by means of optical images that are captured subsequently in the vertical direction above the solid surface with a constant step. Stepping the camera vertically with a step that is smaller then the depth of optical field, a convenient set of optical sections may be obtained from which the sophisticated software creates the 3D relief.

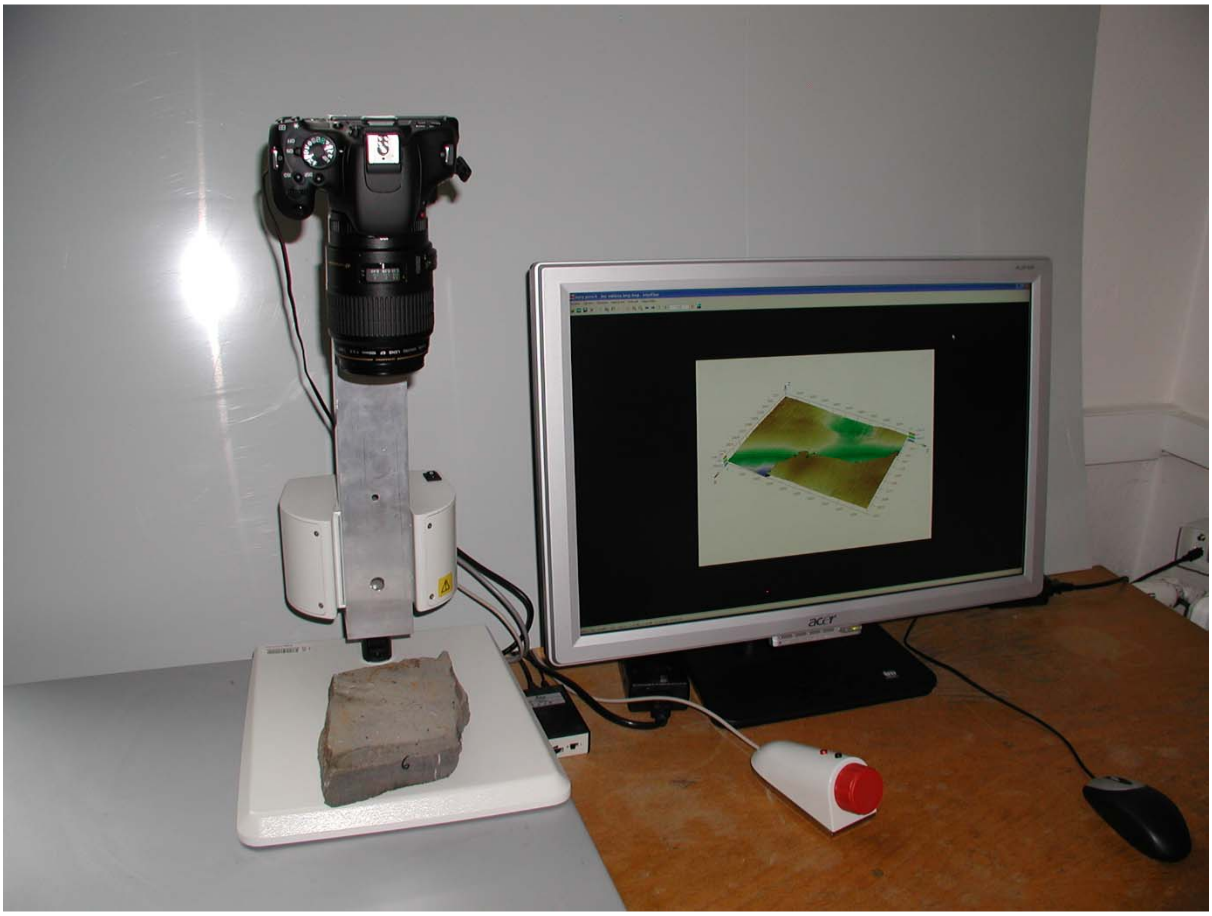

Figure 1. Digitizing device used for laboratory reconstructions of 3D reliefs of rock joints

The situation with common optical devices is rather problematic. Although they are capable of producing optical sections at precise heights, their images contain besides sharp points also blurred ones, whose heights cannot be identified reliable. In addition, due to a larger depth of optical field, there are always several optical sections in the acquired set of images that comprise the same points with the same sharpness and this makes their heights indistinguishable. All these drawbacks have to be solved by sophisticated software. There are several software solutions among which the Fourier sharpening is the most powerful solution and thus it has been implemented in the computer program [7]. Figure 1 shows a prototype of the digitizing device that is convenient for laboratory purposes. It consists of the photographic digital camera Canon EOS 600D movable in the horizontal direction above the specimen of the rock joint. The camera is connected with the computer that stores the images and process them into a final 3D relief shown on the screen.

Figure 2. Digitizing device used for terrain reconstructions of 3D reliefs

However, the device adapted for laboratory reconstructions can hardly be usable in terrains. For terrain reconstructions, where large specimens are to be processed, the support has to be rearranged. Figure 2 presents the new arrangement convenient for terrain applications. At first, we have tested vertically situated rock reliefs and thus the movement of the camera was oriented horizontally using two tripods as shown in figure 2. The camera remained the same as in the laboratory assembly and was connected with the notebook that stored the set of acquired images. The horizontal movement of the camera is realized manually along the meter gauge. This horizontal stepping and taking snaps provide series of optical sections whose digital representatives serve as input data for special software. The data from the camera are transferred to the computer via USB cable. The software installed in the computer accomplishes the 3D reconstructions of surface reliefs. The reliefs with characteristic sizes about 30cm x 20 cm were tested (digital resolution 5184 pixels x 3456 pixels) but in principle the device may reconstruct still larger formats reaching up to several meters.

3. Results and discussions

Figure 3 shows one of the reconstructed rock reliefs. Image A) presents a bird's view on real rock relief and image B) contains its reconstructed copy (side view) put in the Cartesian coordinate system.

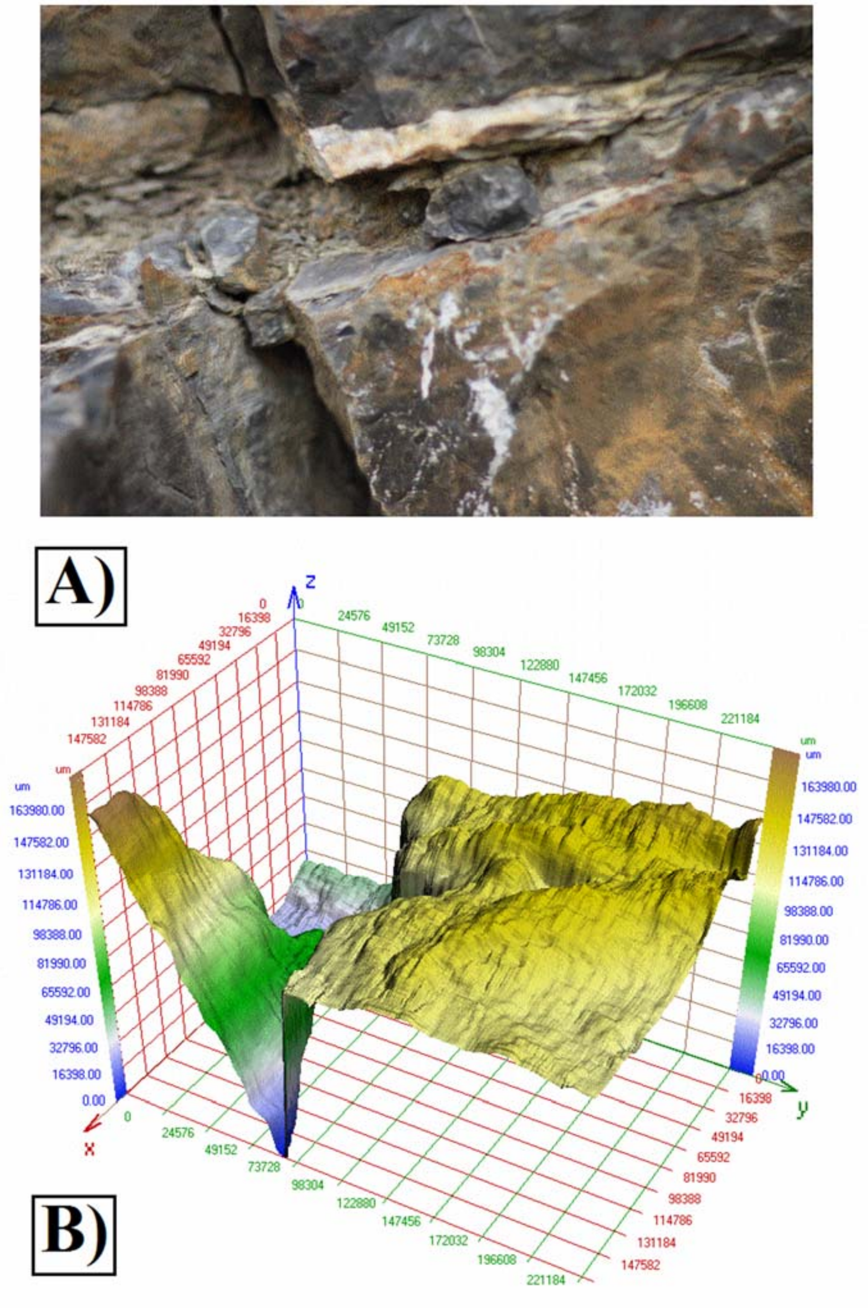

Figure 3. Rock reliefs: A) Photography of the natural relief; B) 3D copy of the relief digitized by the sectional method (after [8]).

As soon as the 3D reliefs are digitized by the sectional method, various height characteristics may be computed as, for example, the global parameter called the root-mean-square (RMS) parameter of the relief that is expressed by a function of two variables $f(x, y)$

$$RMS = \frac{1}{C \cdot D} \int_0^C \int_0^D | f(x,y) | dxdy \qquad (2)$$

where C and D are length and width of the relief format. In practice, the function $f(x,y)$ is treated discretely $f(x_i, y_j)$ and integration is replaced by summation.

Indicator (2) and other parameters enable a numerical comparison with the equivalent parameters of the standard 3D reliefs whose *JRC* coefficients are known and on the basis of the most similar couples (investigated relief versus standard relief) to determine *JRC* of the investigated rock joint. All these operations are performed automatically on the computer. A detailed description of this procedure can be found elsewhere [8].

4. Conclusions

The sectional method discussed and tested in this contribution does not require any special hardware for creating 3D reliefs of rock specimens. It is capable of utilizing common optical systems like commercial digital photographic cameras. This makes the sectional method much cheaper compared to other similar method. The sectional method along with sophisticated software is capable of processing variety of formats ranging from small rock specimens to large terrain specimens.

When adding comparative technique based on similarity between investigated rock reliefs and the standard ones (with known JRC), a numerical computer procedure is established which is capable of evaluating *JRC* of the investigated rock joints, too. Such a system may have a potential to become a usable tool in geotechnical practice.

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