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Defining a graphical basis for developing roughness model of discontinuity

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Abstract

The paper shows how to create graphic backgrounds from photographs of actual discontinuous surfaces of soft rock mass samples. The need for this activity is based on the necessity of creating numerical models of roughness and their connection with traditional methods of assessing the roughness of discontinuities.

This paper takes a part of experimental research of time-dependent deformation of soft rock along discontinuities. Experimental research of time-dependent shear strength along discontinuities involved testing of three samples of soft rock – marl, which were sampled from the mine basin Pljevlja. In this case the samples have equal geometric characteristics, regular prismatic shape, with an artificial crack formed on each sample of different roughness of discontinuity surface (smooth, waved and moderately rough). The samples were tested in the laboratory, using the existing equipment with necessary modifications and newly designed equipment to provide for proper conducting of the experiment. As known, behaviour of rock mass primary depends of their discontinuities characteristics.

One of the most important characteristic is form and state of the discontinuity surface. This paper presents the way how to define roughness model that could be useful for making numerical connection between shear strength and roughness of the discontinuity. For mentioned activities, professional photography techniques has been used that obtained quality photos of each discontinuity surface, software Agisoft© for quality loading photos and preparing model of surface and Autocad drawing format that could be used for making numerical equations for determinate connection shear strength and discontinuity roughness.

Keywords

Soft rock, Roughness, Shear strength, Software model, Discontinuity.

1 Introduction

This paper presents a part of more extensive experimental research within the scope of a scientific project (Bujišić M. and Tomanović Z. 2024). Experimental part of the scientific project includes two segments – initial (trial) test and main test. The aim of this article is to show how a digital basis can be obtained for making a numerical relationship between shear strength and roughness of a discontinuous surface of real soft rock samples. The purpose of the scientific project is to provide improved understanding of behaviour of soft rock mass through experiment.

The next steps of the research within the scope of experimental research, aim to add scientific value in terms of obtaining material characteristics of time-dependent behaviour of rock mass for the samples of a simple geometric shape, while contributing to the examination of phenomenon of discontinuity impact on obtaining the foregoing parameters. The idea is to conduct such a test on specimens with discontinuities, sample size 30x15x15(cm) under controlled laboratory conditions, at constant normal loading with incremental shear stress and measurement of deformations. Material used for testing has been sampled from the open pit Potrlica of the coal mine Pljevlja. From the open pit mine, at depth of approx. 25m, measured from the terrain surface was extracted a block of approximately 5.0 m^3 (Fig. 1). Immediately upon excavation, the material was loaded on transport equipment and transported from Pljevlja to Podgorica (approx. 180km). During material sampling, precautions were taken to prevent any damage to rock mass, with due consideration given to a natural orientation of block, hence rock mass with unchanged geometry was prepared for processing. This is very important because of the orientation of sedimentation layers of the natural rock material, which is orthogonally anisotropic.



Fig. 1 Lifting up of the extracted rock mass.



Fig. 2 Samples processed to target dimensions 30x15x15 cm.

During the preparation of the samples, due to the very demanding processing (samples splitting during cutting) of the soft rock mass from nature (irregular shape of rock sample) into the desired shape of sample specimen, the processing success rate was approximately 50%. A specialised plant for processing of stone was used to process material and form cuboid (prism) shaped specimens with dimensions 30x15x15 cm^3 (Fig. 2).

2 Crack formation

An artificial crack was created in laboratory by splitting specimens into two half's. In order for the planes of discontinuity to have a regular shape, a linear weakening was formed along the sample, and then a splitting force was applied at half of height (at approximately 7.5 cm).

At the cut grooves, using a cylinder to apply loading at a controlled rate, the samples were divided into two, approximately equal halves (Fig. 3a and Fig. 3b), followed by forming of discontinuity planes of different roughness (Fig. 4).

The procedure of artificial crack formation was not always successful, because crack propagation in soft rock specimens could not be completely controlled. Due to the natural heterogeneity of the material, sedimentary structure and local variations in strength, some specimens fractured outside the intended weakened plane or developed irregular and branched cracks. In such cases, the obtained

discontinuity surface was not suitable for further laboratory testing or photogrammetric roughness analysis, because the two halves could not be reliably reassembled and the original geometry of the specimen was partly disturbed. For this reason, the overall success rate of preparing specimens with acceptable artificial discontinuities was approximately 50%. An example of unsuccessful crack formation is shown in (Fig. 5).



Fig. 3a Cutting a groove at the sample centre.



Fig. 3b Forming of discontinuity.



Fig. 4 Formed roughness plane of discontinuity.



Fig. 5 Unsuccessful crack formation during specimen preparation.

Upon defining discontinuity planes, all samples were wrapped in foil. Previously, after the geometry had been formed, all the samples were paraffin-coated to preserve their natural moisture content.

3 Creating of roughness model

3.1 Evaluation of the roughness of discontinuities using modern numerical methods

In everyday engineering practice, when assessing the roughness of rock mass discontinuities, traditional methods (e.g. Barton's comb) are used (ISRM, 1978; Barton and Choubey, 1977; Palmström, 2001). The progression of mathematical models in modern engineering has given the possibility to establish numerical formulations that would be used to evaluate the state of roughness more precisely. However, for a long time, the very simple use of traditional methods with satisfactory accuracy had a justified primacy in relation to demanding and time-consuming mathematical calculations. Nowadays, with the development of modern computer aids, it is possible to develop models that are based on the mentioned mathematical formulations, but which solve the problem of the roughness of discontinuities in a much shorter time.

In order to numerically describe the roughness of discontinuous surfaces, it is necessary to obtain a roughness model. Agisoft© software (Agisoft LLC, 2022) was used for these purposes. The creation of the model is based on the import of photos, that is, the import of the real state of the surface of the samples using a certain number of photos. The number of photos is conditioned by the necessity of painting the complete surface from several parts, on the basis of which the software creates the model. The quality of the model depends on the quality of the photos. After creating the model, it is possible to export the non-continuous surface into a digital 3d surface file (in this case .dwg). In this way, taking into account the scale of the obtained profiles, it is possible to derive a mathematical formulation of the curvature for each profile made, and based on known postulates and theories about the roughness of discontinuities, it is possible to derive the mathematical dependence of roughness and shear strength of discontinuities.

3.2 Production of photos for model

For making a quality model of discontinuity planes with roughness, it’s necessary to prepared high quality photos (Fig. 6). For all 20 specimens that was analysed in the experimental research several photos of each roughness plane has been made (Fig. 7).



Fig. 6 Making a photo.



Fig. 7 Photo of roughness plane.

It is very important that every photo has a surface which could be found in the next one from the same collection. In this way the software will recognize the same relief structures of discontinuous surfaces in order to form a usable roughness model.

3.3 Making roughness model

As mentioned earlier, creating graphic backgrounds from photographs of actual discontinuous surfaces is based on the necessity of creating numerical models of roughness and their connection with traditional methods of assessing the roughness of discontinuities.

Photos of discontinuity surface for all samples were made in high quality resolution (300 dpi).

Agisoft© software package is used to create roughness models of the samples. The program works on the principle of importing photos on the basis of which the model is created. In order for the model to be used as an output data, it is necessary to ensure the matching of the size of the samples in the model and in the export file. In this regard, half of the sample in both directions was marked with red points on all samples before photography, which were later used in the model as reference points for adjusting the scale in the digital file. The quality of the model also depends on the density of the points that form it. Through an iterative procedure, the number of points that gives a high-quality model and whose processing did not require irrational processing time was adopted.

Figure 8 shows an example of a surface that can be export in cad file and with a scale in real dimensions it could be analysed for the next stage. In cad file, we could see lines that define the roughness surface.

During the research, it is planned to make 5 longitudinal profiles at the same distance from each other on each sample model. Every sections will be made of many local bumps.

In order to provide a numerical description of the roughness, it is necessary to represent the obtained surface roughness by means of a certain easy-to-use method. Previous studies have shown that both 2D profile-based descriptors and 3D surface parameters can be successfully used for quantitative characterization of rock joint roughness and for interpretation of shear strength behaviour (Tse and Cruden, 1979; Grasselli and Egger, 2003).

The wider research is planned to develop a numerical method for estimating discontinuity roughness based on 2D profiles, with the aim of establishing correlation with the JRC concept proposed by Barton and Choubey, as well as with numerical roughness descriptors such as Z_2 introduced by Tse and Cruden. The mechanical interpretation of the influence of inclined roughness elements on peak shear strength is also consistent with the earlier shear-strength model proposed by Patton (Patton, 1966; Barton and Choubey, 1977; Tse and Cruden, 1979).

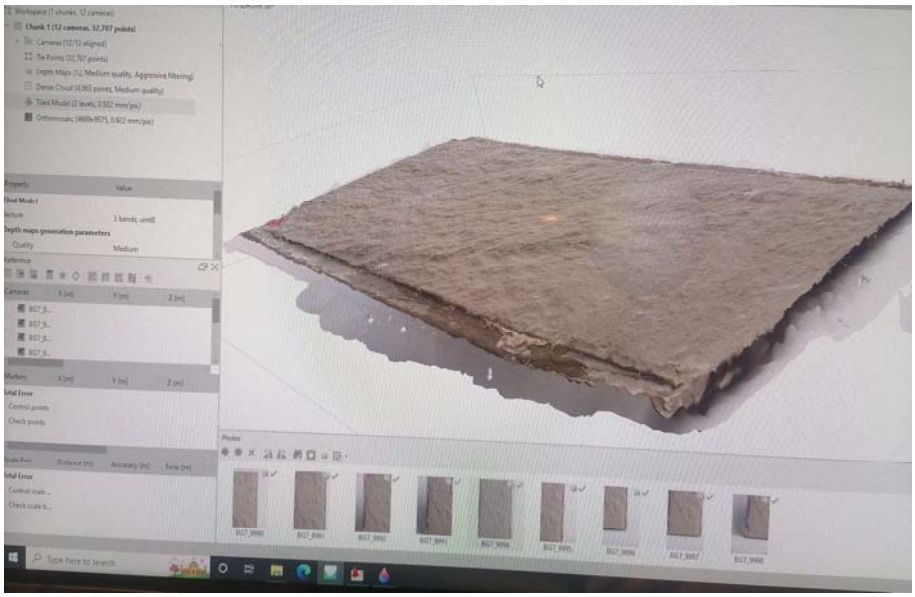


Fig. 8 Model made by photo.

Following it is planned to use the five 2D profiles obtained by 3D surface, that could be used for develop numerical equations based on shear strength of each small triangle along the entire each line of discontinuity. After that, correlation of roughness and shear strength of each of five profiles could provide the roughness behaviour of the surface.

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