Strain analysis in diametral compression test through digital image correlation

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Abstract

In the search for alternatives to obtain more information from rock tests and to make them more accessible, this study applies the Digital Image Correlation technique (DIC 2D) in a diametral compression test called Brazilian Test, comparing the result measured by an extensometer with the result obtained by DIC. Rock tests provide information about rock characteristics applicable to several engineering areas, such as mining and construction. In tests using strain gauges to measure strain, the equipment is expensive and there is a risk of breaking the instrument due to the contact with the specimen. However, tests measuring strain through the DIC technique may be more accessible, using open source software and lower cost equipment when compared to the cost of the extensometers. The results of this study demonstrate that the DIC technique enables: 1) complementing the information of diametrical tests obtained using strain gauges, for example, supporting the visualization of crack propagation; and 2) in some cases, replacing the use of extensometers, as far as a variation is tolerated.

Keywords: Digital Image Correlation, rock mechanics, extensometer.

1. Introduction

According to Azevedo and Marques (2002), rocks are consolidated solid materials, formed naturally by aggregates of mineral matter. Their internal cohesion – the force that binds the particles to each other – and the tensile strength are the main properties that distinguish them from soils.

Due to the large variation in rock properties, some basic measurements are taken as a reference to describe the rocks quantitatively. These properties are known as index properties, obtained through rock samples and they are relatively easy to measure. These properties are physical indices that reflect the structure, composition and mechanical behaviour of rocks, such as moisture content, wave propagation velocity, durability, strength, porosity and permeability.

In rock compression tests to measure radial and axial strain, load cells, strain gauges and position transducers are used. The linear displacement can be measured by a position transducer, known as LVDT (Linear Variable Differential Transformer). Strain gauges are attached to the specimen and they are discarded after the test.

In rock mechanic studies, empirical analyses are used to assess rock behaviour. The Brazilian test is used as an indirect way of determining the tensile strength of a rock. Also known as indirect traction test, this test follows ISRM (International Society for Rock Mechanics, 1978) or ASTM D 3967 (American Society for Tests and Materials, 2008) international standards. In the test, the specimen is placed directly in contact with the press and the applied force should be distributed in a range, rather than linearly, thus avoiding high concentrations of stress at the points of contact. Figure 1 illustrates the tests following the parameters of the two international standards.

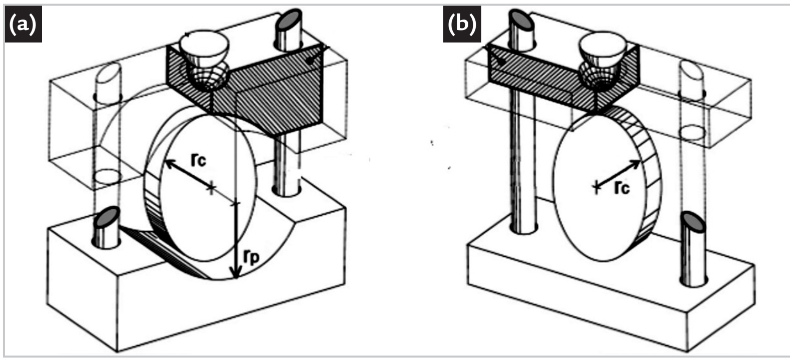

Figure 1 - (a) Brazilian test following ISRM (1978); (b) Brazilian test following D3967 standard (ASTM, 2016). (adapted from Markides and Kourkoulis, 2016).

An alternative to assess rock behaviour in diametrical tests is the use of Digital Image Correlation (DIC 2D). In DIC, the specimen is painted to obtain a random surface pattern. During the test, single points of the specimen surface are identified in all frames of the test video, evaluating rock strain and crack propagation through a correlation algorithm. DIC, also known as photogrammetry, was developed in the early 1980s at the University of South Carolina, in the United States, as a method for total analysis of surface strain (Peters & Ranson, 1981; Peters & Ranson, 1982; Sutton et al., 1983; Chu et al., 1985). A schematic representation of the equipment is shown in Figure 2.

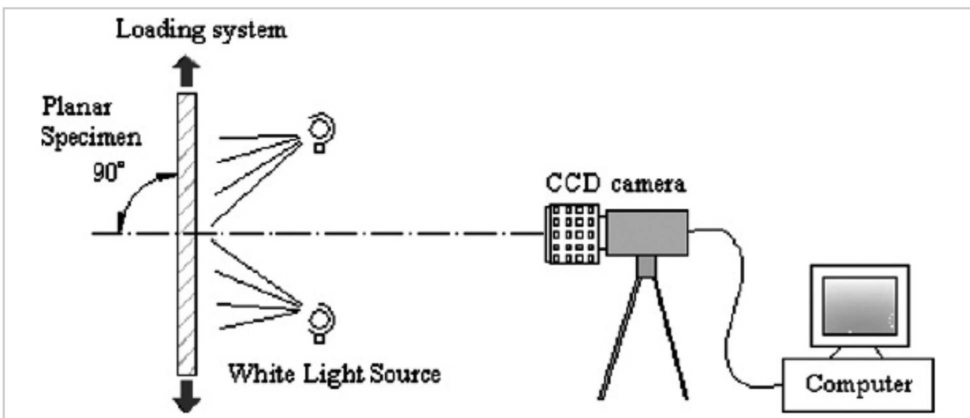

Figure 2 - Schematic representation of equipment to capture 2D images (PAN *et al.*, 2009).

The main objective of this study was to apply the DIC technique to a diametrical compression test comparing the displacement obtained by instrumentation versus CID. In the test, the specimen was instrumented and loaded without breaking the specimen. Low cost photo camera and image correlation freeware were used. The specification of the traction test through diametrical compression followed the recommendations of the ISRM.

2. Material and method

To perform the test, it was necessary to prepare the specimens, install an extensometer, arrange the image capture system and measure the digital image correlation, as detailed below.

2.1 Preparation of test specimens

Cylindrical specimens with a diameter of 91.0mm and a height of 75.0mm were prepared according to the ISRM specification. Then the surface of the specimen was prepared by applying a white background followed by a black paint spray to create contrast in the surface that is necessary for the analysis. Figure 3 illustrates the process of preparing the specimen surface.

Figure 3 - Preparation of the specimen surface.

In image analysis, the texture on the specimen surface is represented by a matrix whose values correspond to the intensity of each pixel. Figure 4 illustrates this representation. Each point chosen has a unique matrix identified in all frames of the video, thus enabling the analysis of strain by DIC.

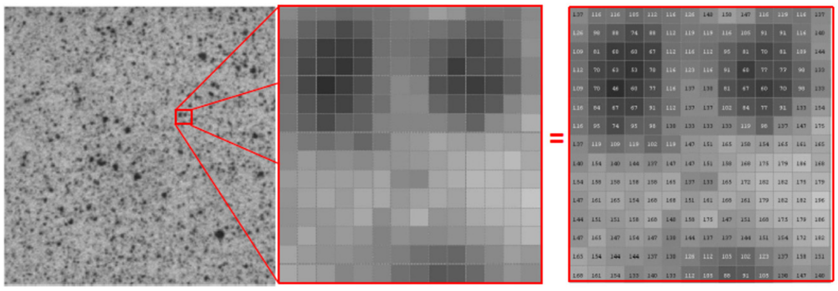

Figure 4 - Digital representation of texture on the specimen surface (SUTTON *et al.*, 2009).

2.2 Installing the strain gauge

The strain measured through DIC technique is compared with the strain measured by a strain gauge. The strain gauge is installed on one side of the specimen, and on the other side, the surface will be painted to enable data collection through image. The equipment was assembled as in Figure 5. A servo-controlled press model MTS815 was used and the force application rate was 0.05kN/s, limiting the test to 40kN.

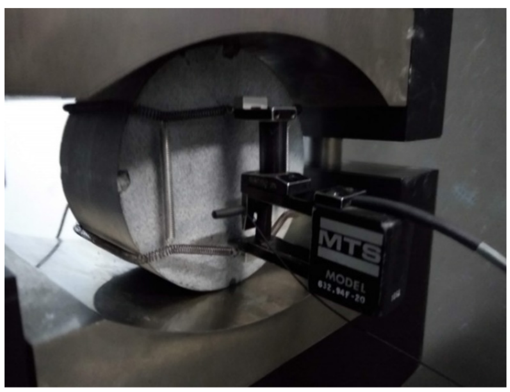

Figure 5 - The strain gauge assembled on the specimen.

2.3 Assembling the image capture system

Shooting was done with a Nikon D7000 digital camera installed on a tripod and a circular led light was adapted. A Tokina 100 F 2.8D macro lens and a polarizing filter were used. The test was shot and the video was then divided into frames using a freeware, in order to obtain as few frames as possible, improving image processing time without compromising the results. Figure 6 illustrates the equipment used in the test and Figure 7 shows how it was assembled for the test.

Figure 6 - Video recording equipment used for the test: camera, lens, polarising filter and circular led light.

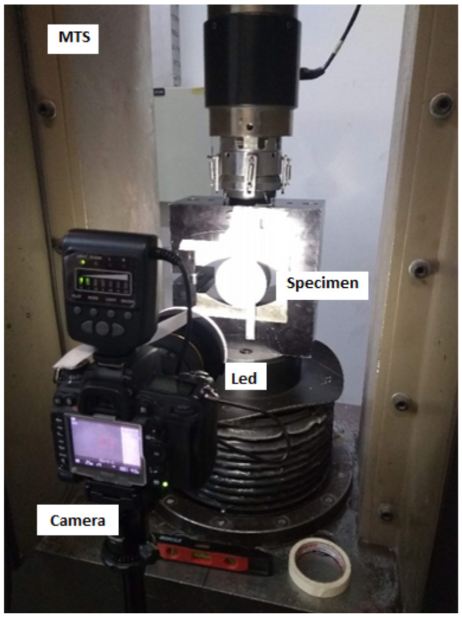

Figure 7 - How the video recording equipment was assembled for the test.

2.4 Measurement of digital image correlation

The strain analysis through digital image correlation was conducted using a GOM Correlate system, supplied by GOM Optical Measuring Techniques. As described in the specimen preparation step in the Methodology, DIC requires the specimens to be spray-painted to create a non-uniform surface pattern, which is tracked by the GOM Correlate software based on the digital images captured during the test. The test video was split into JPG frames using Free Video to JPG Converter freeware. The test video, lasting approximately 15 minutes, was divided into 93 frames to reduce image processing time, without compromising the information collected. The quality of the specimen preparation was tested using GOM Correlate software prior to performing the test. Figure 8 shows a specimen within the specifications at the top, and a specimen out of specification at the bottom, as demonstrated by the points not recognized by the software (in blank).

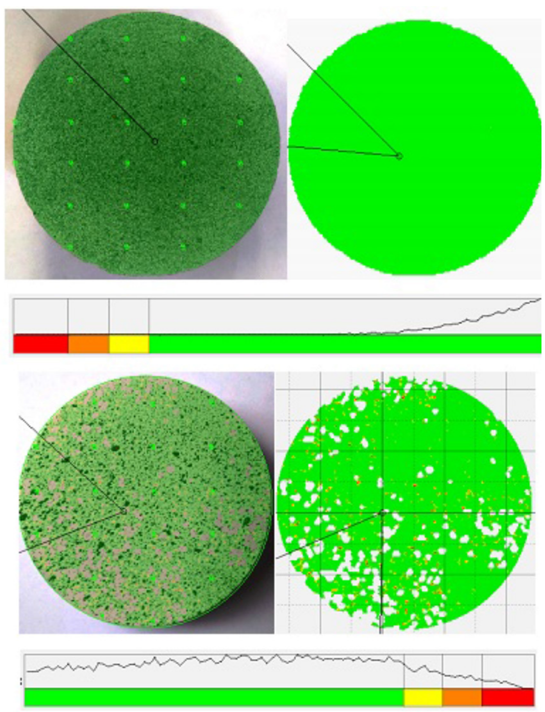

Figure 8 - Testing the quality of specimen preparation using GOM Correlate software.

3. Results and discussion

Figure 9 shows the results obtained in the vertical strain test with one stage test load. With this feature, the images also support the assessment of displacement and crack propagation. Figure 10, based on the points in the surroundings of the extensometer, shows the strain obtained along the loading, with strain of approximately 0.58mm measured by DIC.

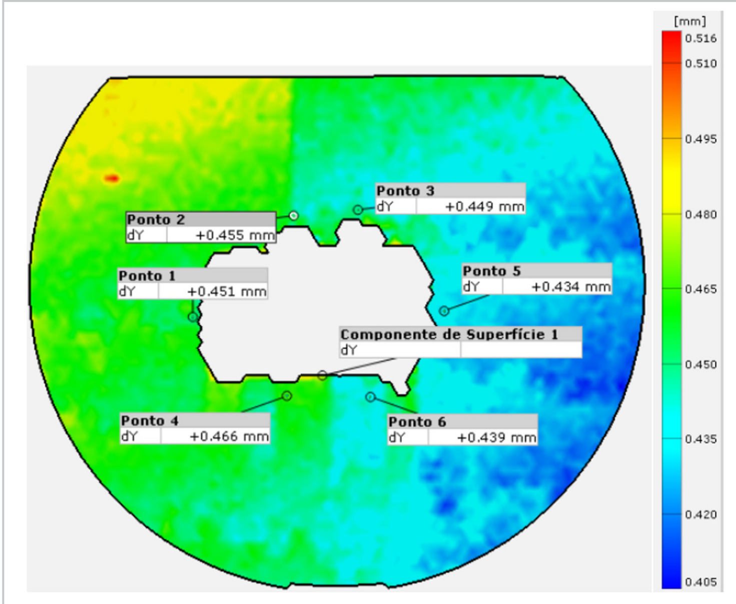

Figure 9 - Example of displacement in one stage test load.

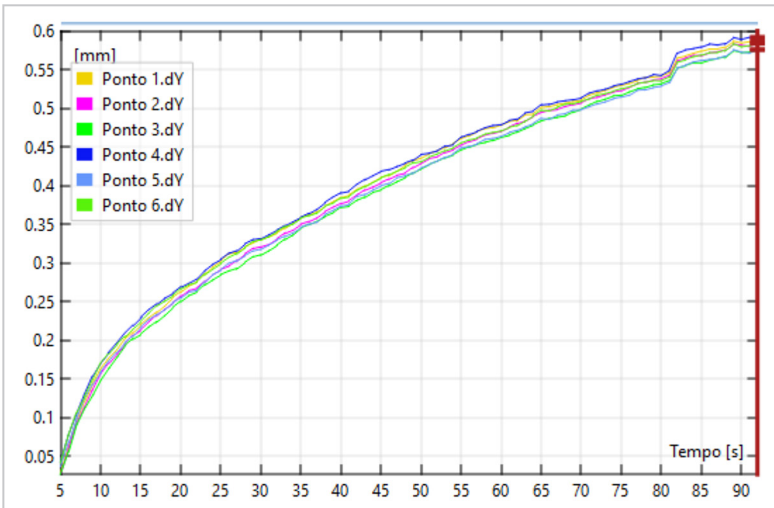

Figure 10 - Strain obtained by DIC during the test.

The strain measured through the extensometer is presented in Figure 11, reaching 0.48mm. The difference of 0.10 mm between the measurement of the strain through DIC and through strain gauge corresponds to 17%. This difference may be related to the fact that the points selected to determine the strain are located surrounding the extensometer, and therefore, they are not exactly the central point measured by the extensometer. In addition, variables associated with image analysis, such as camera angle, illumination, and parallelism can be better handled by using templates that facilitate assembly.

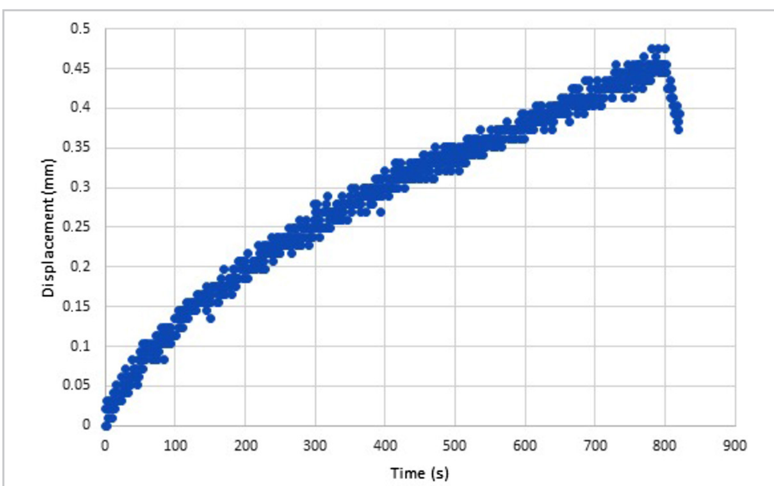

Figure 11 - Strain measured through strain gauge.

4. Conclusion

According to the results, in this first study, there was a 17% variation comparing the strain of the specimen measured through DIC with the strain measured using an extensometer. However, the DIC technique proved to be promising in the analysis of strain in rock tests that allow such variation and require a reduced cost. A future development stemming from our contribution could be suggestions for repeating the test, including a complete test – until it reaches pre-peak – in order to obtain a more comprehensive database to compare both measurement techniques.

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