A suggested method to interpret direct shear test results based on the current state of the practice

The direct shear test (DST) is widely used to determine the shear strength of natural discontinuities in rocks and soils. This determination is of particular importance when designing rock-based engineering structures and assessing failures.

Direct shear tests are performed using a shear box apparatus that maintains a constant force normal to the discontinuity while applying an increasing shear force parallel to the discontinuity (ASTM, 2016). The information recorded includes the applied normal force, displacement of the top of the specimen in relation to the bottom, the shear force applied to achieve that displacement, and fracture roughness.

The test is generally performed three to four times with increasing applied normal loads, resulting in a set of traces corresponding to the applied normal forces. Recorded forces are then converted to stresses by dividing by the surface contact area measured at the time of the test. Two parameters are calculated based on the trace data described above (ASTM, 2016):

- Peak shear strength is associated with the maximum shear stress value along a sheared surface attained during a test.

- Residual shear strength is associated with the point at which the shear stress remains essentially constant with increasing shear displacement.

Once a shear strength value has been chosen from each of the traces that compound the test, these are matched to the corresponding normal stresses and depicted in a shear stress versus normal stress plane.

The peak shear strength for a sample can generally be determined from the maximum shear stress value attained. In contrast, the determination of the residual shear strength can be a complicated and subjective process in cases where the behavior of the post-peak section of the trace is fluctuating.

The post-peak region is defined as the full section of the shear stress displacement curve after the peak shear stress has been reached. Figure 1 shows a dataset for which the post-peak region is variable and the selection of a residual shear stress value is more challenging and potentially dependent on practitioner judgment. The fact that the interpretation of datasets is the product of the expertise and judgment of designers represents a potential source of variability in direct shear testing.

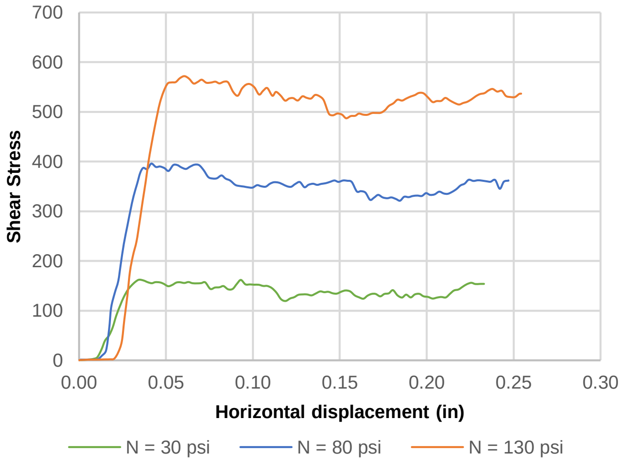

Fig 1. Direct shear traces for open quartz monzonite fracture (study sample obtained from University of Arizona Rock Mechanics Laboratory).

A number of suggested methods and standards, including Gyenge and Herget (1977), Hencher and Richards (1989), and Muralha et.al. (2014), discuss the calculation of shear strength parameters from both the peak shear stress and residual shear stress. However, there is a notable absence of detailed discussion on how to identify or select this residual shear stress when the behavior of the residual portion of the stress-displacement curve is not steady and several fluctuations are perceived.

Once the choice of points that represent stresses from the shear stress-displacement curve is varied, the friction and cohesion parameters will vary accordingly. Knowing this, it is clear that this election of points represents another source of variability for a direct shear test coming from a human factor. This discrepancy in results caused by the decisions of a practitioner is not being recognized as far as the literature review goes. There is an evident lack of methodologies for determining residual shear strength for cases where the behavior of the post-peak section of a trace is fluctuating.

The goal of this research is to quantify and assess the variability introduced by differing methods of interpretation of direct shear test results and associated corrections and conversions. To achieve this, a survey was developed and is currently being distributed to engineers and laboratory technicians to understand in depth how they perform the interpretation of a direct shear test.

The survey has three main parts. The first part contains questions about the background of the practitioners, such as years of experience with direct shear tests, past education, the type of company they work for, and the country where they are based. The second part contains results from five direct shear tests of varying difficulty and the practitioners are asked to choose shear stress values, explain how they decide on those values, the preferred method for fitting a curve through the points, and what the obtained results for friction angle and cohesion were for both the peak and residual parts. Finally, the last part asks general questions about correction factors, preferred fitting methods, and the impact of changing test conditions, such as presenting a single-stage test vs. a multi-stage test or the shift from surface mining to an underground project.

Upon the end of the survey time and the acquisition of results, the goal is to suggest a method for interpreting direct shear tests. This method will be derived from the responses of the participants and is intended to be an aid and an approach to standardize the practice of interpreting direct shear tests, aiming to decrease the variability observed in the friction and cohesion parameters.

The survey will also allow grouping responses into different categories, such as how test results are interpreted in the U.S. compared to Australia or how mining company workers interpret the tests compared to consultants. The survey is designed to gain a detailed understanding of individuals' profiles and their specific methods of analyzing direct shear tests.

REFERENCES

1. ASTM. (2016). Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force.
2. Gyenge, M. and G. Herget. (1977). Determination of strength properties of rock discontinuities by direct shear test. *Pit slope manual supplement 3-2:* Laboratory tests for design parameters, Canmet report 77-26: 37-44.
3. Hencher, S.R., and L.R. Richards. (1989). Laboratory direct shear testing of rock discontinuities. *Ground Engineering*, 22, 2: 24-31.
4. Muralha, J., Grasselli, G., Tatone, B., et al. (2014). ISRM Suggested Method for Laboratory Determination of the Shear Strength of Rock Joints: Revised Version. *Rock Mech Rock Eng* 47, 291–302. https://doi.org/10.1007/s00603-013-0519-z