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Investigation on residual friction coefficient of rock surfaces under small and standard contact sizes and suggestion the application of tribometer to measuring it

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Abstract

Investigation and determination of residual frictional properties of rock joints is important for designing structures on or within the rock masses. Tribometer is a device to measure frictional properties of various types of contacting surfaces. In this research, several direct shear experiments conducted on two types of artificial limestone joints named Onyx marble and Travertine. Two types of surfaces geometry such as rough tensile joint surfaces with standard dimensions (based on ISRM suggested methods) and grinded planar small surfaces with dimensions ranged from 1 cm2 to 25 cm2 were prepared. Direct shear experiments by constant shearing rate and under different normal stresses conducted in CNL boundary condition. Results obtained from the residual state of the shear were gathered and investigate and it found that the residual friction coefficient of limestone rock joints, under almost similar normal stress and shearing rate conditions, remains approximately constant with differing the contact size of the specimens. In addition, under approximately similar stress concentrations in contact regions, the residual shear behavior of rough surfaces with standard dimensions is very similar to that of small planar ground surfaces in limestone joints. Finally, based on findings in this research and some other past researches, it is proposed to apply tribometers for measuring the residual shear strength of rock joints. In this paper, a conceptual design of a tribometer is proposed to develop for measuring residual frictional properties of a point contacts of rock surfaces during 5 to 20 mm shear displacements.

Keywords: *rock joint shear strength, stress concentration on roughness, scale independency of residual shear, CNL shear*

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Extended Abstract:

1. Introduction

Understanding the residual friction coefficient of rock joints is important for designing safe excavations in the rock masses. Because, rock mass failure commonly governed by the shear behavior of discontinuities, specially at shallow depth (Hoek, 2007). Joints residual shear strength sometimes can be considered as corresponding to the rock's residual strength (Cai et al. 2007) that is a material property which depends on the type of rock considered. The residual shear strength of rock joints usually is lower than the peak shear strength and is defined by the level of load bearing capacity after the peak shear strength under a large shear displacement (about 5–10 times the peak shear displacement; Cai et al. 2007).

experimental investigation the surfaces having different contact areas showed that under the constant normal stress and shearing rate, the residual friction coefficient of planar limestone rock surfaces is independent of the contact area (Mehrishal et al. 2017a). It means that, by increasing or decreasing the contact area, the applied normal force must increase or decrease to maintain a constant stress. Therefore, the residual coefficient of friction, which is defined as the ratio of shear force to applied normal force, remains constant.

The simultaneous modelling of the frictional behaviour (sliding-cohesion-dilation-wear) of real rock joints were complex and less reliable due to the roughness of both upper and lower contact surfaces. Also, in-situ direct shear experiments are much time consuming and expensive. But, nowadays results obtained from extensive researches on shear behaviour of rock joints have led to a good understanding of the mechanisms by which different factors affect the friction of rock surfaces. Therefore, now it is the time to apply these findings and invent a simple and suitable method to accurately evaluate the frictional behaviour of rock joints.

Tribometers are devices that are used to measure frictional and wear properties of various types of contacting surfaces. Tribometers are the basic technology used in most of the tribological investigations. A carefully selected tribometer can simulate all the critical characteristics of a wear or friction problem without the difficulties associated with the experimentation on actual equipment. The purpose of a tribometer is to provide simulation of friction and wear under controlled conditions. all tribological studies require the application of typical tribometers with a dynamic contact. In this paper the feasibility of the application of small contact sizes samples instead of standard joints specimens, for measuring the residual shear strength of rock joints, under constant normal stress and shearing rate are investigated.

2. Materials and methods

In this research, several direct shear experiments conducted on two types of artificial limestone joints named Onyx marble and Travertine. Two types of surfaces geometry such as rough tensile joint surfaces with standard dimensions and grinded planar small surfaces with dimensions ranged from 1 cm^2 to 25 cm^2 were prepared. Direct shear experiments by constant shearing rate and under different normal stresses conducted in CNL boundary condition. The variations of contact ratios and stress concentration versus the shear displacements during direct shear tests were investigated for rough joint samples and results are summarized in table 1. Therefore, in order to make a valid comparison, the effective normal stress on planar small joint samples were defined based on values of concentrated normal stresses. because the effective normal stress which affects the residual shear

strength of rough joints is larger than the initial normal stress due to the stress concentrations caused by mismatch roughness and decreased contact area.

Table 1. contact ratios and average normal stress concentration during residual shear.

Rock type	Initial normal stress (MPa)	Contact ratio during residual state (%)	Mean concentrated normal stress (MPa)
Onyx Marble	0.5	8	6
	2	14	14
	4	17	24
Travertine	0.5	13	4
	1	20	5
	3.5	30	12

3. Results and Conclusion

Results obtained from the residual state of the shear were gathered and investigate and it found that the residual friction coefficient of limestone rock joints, under almost similar normal stress and shearing rate conditions, remains approximately constant with differing the contact size of the specimens. In addition, under approximately similar stress concentrations in contact regions, the residual shear behavior of rough surfaces with standard dimensions is very similar to that of small planar ground surfaces in limestone joints. Finally, based on findings in this research and some other past researches (Mehrishal et al. 2017), it is proposed to apply tribometers for measuring the residual shear strength of rock joints. In this paper, a conceptual design of a tribometer is proposed to develop for measuring residual frictional properties of a point contacts of rock surfaces during 5 to 20 mm shear displacements (Figure 1).

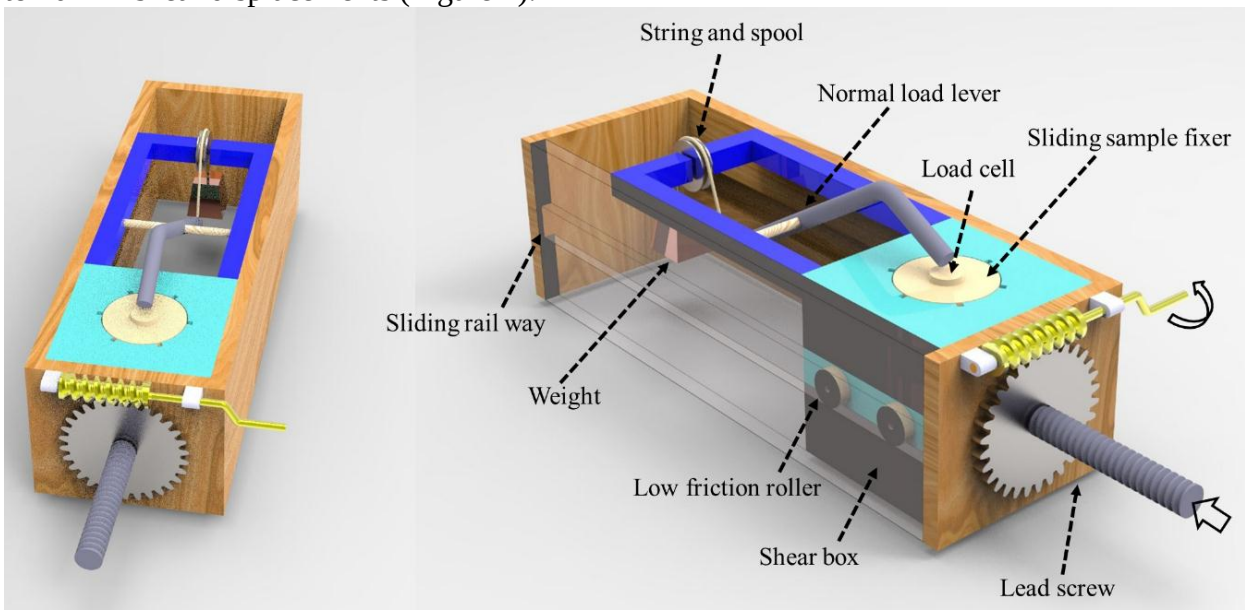

Fig. 1.conceptual model of a portable tribometer for measuring residual friction coefficient of rocks.

References:

Bowden, F. P., & Tabor, D. 2001. The friction and lubrication of solids (Vol. 1). Oxford university press.

Cai, M., Kaiser, P. K., Tasaka, Y., & Minami, M. (2007). Determination of residual strength parameters of jointed rock masses using the GSI system. International Journal of Rock Mechanics and Mining Sciences, 44(2), 247 265.

Chen, J. H., & Ursell, C. R. 1979. Comparison of Wire Rope Life Using Nylon and Steel Sheaves-Part 1: Test Methodology and Comparison of Wire Rope Endurance Life (No. 790904). SAE Technical Paper.

Crowder JJ, Bawden WF. 2004. Review of post-peak parameters and behaviour of rock masses: current trends and research. Rocnews.

Gao FQ, Kang HP. 2016. Effects of pre-existing discontinuities on the residual strength of rock mass—insight from a discrete element method simulation. J Struct Geol 85:40–50

Hoek, E. 2007. Practical rock engineering. e-book. Toronto: Rocscience (electronic resource).

Jaeger, J. C. 1971. Friction of rocks and stability of rock slopes. Geotechnique, 21(2), 97-134.

Labrie D. 2017. Frictional properties of rocks as a function of rock type, specimen size and confining pressure. In: The 51st US Rock Mechanics Symposium. American Rock Mechanics Associatio.

Mehrishal, S., Sharifzadeh, M., Shahriar, K., & Song, J. J. 2016. An experimental study on normal stress and shear rate dependency of basic friction coefficient in dry and wet limestone joints. Rock Mechanics and Rock Engineering, 49(12), 4607-4629.

Mehrishal, S., Sharifzadeh, M., Shahriar, K., & Song, J. J. 2017. Shear model development of limestone joints with incorporating variations of basic friction coefficient and roughness components during shearing. Rock Mechanics and Rock Engineering, 50(4), 825-855.

Mehrishal, S., Sharifzadeh, M., Shahriar, K., 2017., Friction and cohesion mechanisms in rock joints shear strength. PhD thesis, Amirkabir university of technology of Tehran, Iran.

Paterson, M. S., & Wong, T. F. 2005. Friction and sliding phenomena. Experimental Rock Deformation—The Brittle Field, 165-209.

Popov, V. L. 2010. Contact mechanics and friction (pp. 231-253). Berlin: Springer Berlin Heidelberg.

Scholz C H, Engelder J T, 1976 The role of asperity indentation and ploughingin rock friction: Asperity creep and stick-slip. Int. J. Rock Mech. Men.and Geomech. Abstr. 13, 149-154.

Scholz, C. H. 2019. The mechanics of earthquakes and faulting. Cambridge university press.

Singh, H. K., & Basu, A. 2018. Evaluation of existing criteria in estimating shear strength of natural rock discontinuities. Engineering Geology, 232, 171-181.

Stachowiak, G., & Batchelor, A. W. 2004. Experimental methods in tribology (Vol. 44). Elsevier.

Walton, G., Labrie, D., & Alejano, L. R. 2019. On the Residual Strength of Rocks and Rockmasses. Rock Mechanics and Rock Engineering, 1-13.

Maurer W C. 1966. Shear failure of rock under axial and hydrostatic pressure. In: Proc. 1st Congr. Int. Soc. Rock Mech., Lisbon, Vol. I, pp. 337-34.

Engelder J T. 1974a. Cataclasis and the generation of fault gouge. Bull. Geol. Soc. Am. 85, 1515-1522.