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Study of the interface friction between mesh and rock surface in drapery systems for rock fall hazard control

Ivan Gratchev [a,*], Dong Hyun Kim [a], Matthew Chung [b]

[a] Griffith School of Engineering, Griffith University, Australia
[b] Lend Lease, QLD, Australia

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ABSTRACT

Although drapery systems are commonly used to control rock fall hazard on steep slopes, some elements of their design such as the interface friction between the mesh and ground surface are still difficult to quantify in practice. This technical note presents a new test procedure designed to study the mechanism of rock–mesh interaction in the laboratory. A series of tilt tests and tests with increasing loads were performed to study the effects that number and type of rock–mesh contacts, slope angle, and mesh characteristics had on mesh–rock interaction. The obtained data indicated that the process of interlocking between the mesh and rocks could increase the mesh's resistance to failure as well as decrease the force acting on the anchors during accumulation of rock debris or snow. Some changes to the current guidelines regarding the selection of interface friction angle are also suggested.

1. Introduction

Rock falls are natural phenomena that cause significant damage to structures and transportation routes. To cope with this hazard, several rock fall protection methods such as benches (Alejano et al. 2007), catch ditches (Pierson et al. 2001) and flexible catch fences (Peila et al. 1998) have been developed and employed on steep slopes. In recent years, draped mesh systems have also become a popular method to control rockfall on actively eroded slopes (Bertolo et al. 2009; Giacomini et al. 2012). It generally consists of a steel mesh draped over a steep slope, which is suspended from upslope anchors (Shu et al. 2005). The design of these systems is dictated by engineering judgment and experience, and it primarily depends on the slope conditions and available funding. These days, engineers may consider different support options, including top anchors only or a series of anchors, which are fixed in the field of the mesh to also improve the slope stability (Bertolo et al. 2009).

The use of top anchors only as shown in Fig. 1 has some advantages as it results in lower installation cost and simplified maintenance which involves the removal of rock debris from the base of the slope. Muhunthan et al. (2005) and Shu et al. (2005), who reviewed the performance of drapery systems at several sites in North America, noted that these drapery systems generally functioned well. However, the investigators also reported a few global failures of the whole structure due to extra loads from falling rocks or snow accumulation. These failures highlighted the uncertainties in the design procedure that still need to be addressed. For example, the interface friction between the mesh and the rock surface is a parameter that contributes to the system support by reducing the force that is transferred to the anchors during extra loads. However, it is also a parameter that is rather difficult to quantify in practice as it varies greatly across the slope due to changes in surface conditions. The variety of mesh–rock contacts such as the surface (or interface) friction (Fig. 2a) and the degree of interlocking (Fig. 2b) also add to the complexity of the task. Some guidelines regarding the selection of the interface friction based on the type of slope surface were suggested by Sasiharan et al. (2006). For example, for slopes with very irregular and undulating surfaces, the interface friction angle can be assumed to be about 60°, while for slopes with planar and smooth surfaces, the friction can be in the range of 25–35°. However, these guidelines seem rather general, which may lead to overdesign and extra cost. It is clear that more research needs to be conducted to improve our knowledge about the mechanisms of mesh–surface interaction.

This work seeks to investigate the mechanism of mesh–surface interaction and clarify the effect of interface friction and interlocking on this process. To achieve this goal, a "rock wall" was built to mimic the mesh–surface interaction in the laboratory. A series of a) tilt tests and b) tests with increasing loads acting on the mesh were performed to study the effect of rock shape, slope inclination, and different mesh types on the friction between the rock surface and mesh. This technical note presents and discusses the obtained results.

* Corresponding author.
E-mail address: ivangratchev@gmail.com (I. Gratchev).

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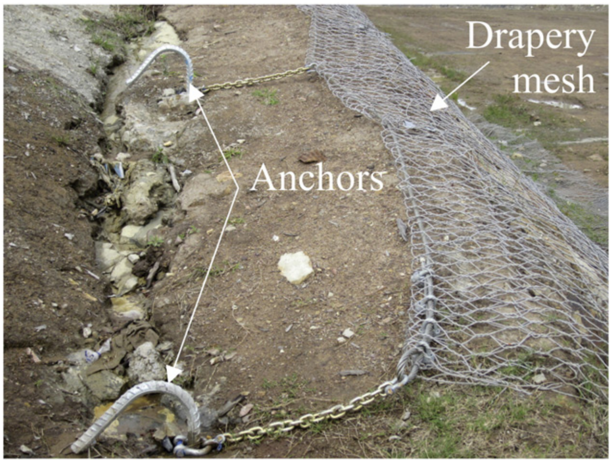

Fig. 1. A view of drapery mesh and anchors system.

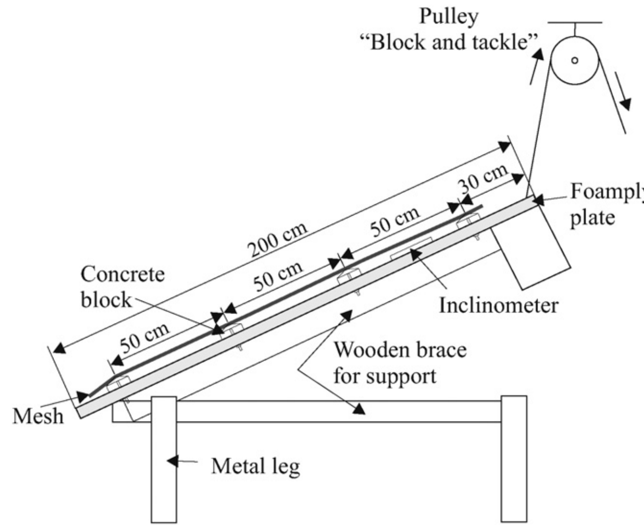

Fig. 3. Experimental setup of tilt tests.

2. Interface friction between the mesh and rocks

2.1. Experimental setup

The experimental setup consisted of the "rock wall" (top part) and the base (Fig. 3). The top part included a 1.2 (width) × 2.0 (length) m foam ply plate with a thickness of 17 mm and a set of concrete blocks of different shapes (Fig. 4). The base part was made of wooden braces and sturdy metal legs to provide support to the whole structure. As the plate was connected to the base through the system of hinges, it was possible to incline the plate at different angles by means of a "block and tackle".

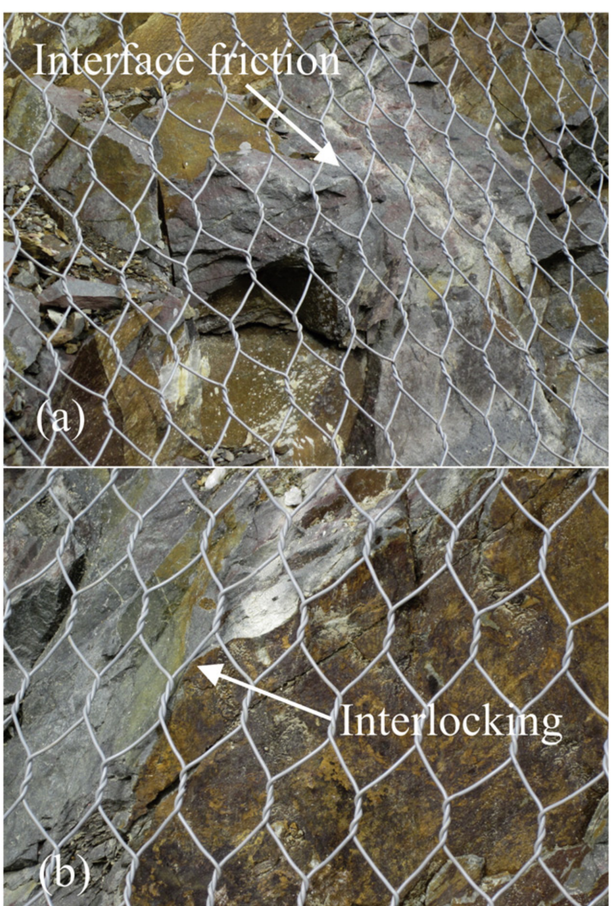

Fig. 2. Types of mesh–rock contacts: a) interface friction, and b) interlocking between the mesh and rock.

The shape of rocks determines the surface roughness including the number and type of mesh–rock contact points. To create different "rock surfaces", several octahedron, round, and square blocks were made of concrete and attached to the plate in different patterns. The shape and size of these blocks are detailed in Fig. 4. The strength of concrete was obtained from three unconfined compression tests on cylindrical samples (diameter of 100 mm, length of 200 mm), resulting in an average UCS value of 50 MPa. The octahedron-shaped blocks were used to produce the interlocking type of contact between the mesh and blocks (Fig. 5a) while the round-shaped blocks only enabled the surface friction as shown in Fig. 5b. The square blocks could produce both types of mesh–rock interaction (Fig. 5c) and were considered as "intermediate" between the octahedron and round shapes.

Maccaferri double-twisted hexagonal mesh without (it is referred to as "DT" in this work) and with PVC coating ("DTC"), and Geobrugg chain link (single-twisted) mesh ("ST") were used to investigate the effect of mesh fabric on the mesh–rock interaction. The details of each mesh are given in Fig. 6. The following features are noted: a) both DT and DTC were more rigid than ST, b) the opening size of DT ($\phi = 78$ mm) and DTC ($\phi = 76$ mm) was greater than the one of ST ($\phi = 67$ mm), and c) due to the PVC coating, the wire diameter of DTC was slightly greater (3.7 mm) compared to ST (3 mm) and DT (2.7 mm).

2.2. Test procedure

To study the interface friction between the mesh and rock surface, a series of tilt tests were performed. The top plate was first lowered to its initial, horizontal position and blocks of the same shape were attached to the plate. For each next testing setup, the number of blocks increased (by twofold) to produce a greater number of mesh–block contact points. From the authors' experience, the largest number of contact points in each arrangement was made when the blocks were placed further apart from each other. Considering the above, the following block arrangements were used (Fig. 7): 2 blocks – (location B2 and B15), 4 blocks – (B1, B4, B13, and B16), and 8 blocks – (B1, B4, B5, B8, B9, B12, B13, and B16).

The mesh was placed on the top of the blocks, and the plate was then slowly lifted by the block and tackle system. The tilt angle (α) was monitored during testing by means of an electrical inclinometer, and the critical tilt angle at which the mesh failed (e.g., the mesh began to