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Comparing the reinforcement capacity of welded steel mesh and a thin spray-on liner using large scale laboratory tests

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ABSTRACT

Steel mesh is used as a passive skin confinement medium to supplement the active support provided by rock bolts for roof and rib control in underground coal mines. Thin spray-on liners (TSL) are believed to have the potential to take the place of steel mesh as the skin confinement medium in underground mines. To confirm this belief, large scale laboratory experiments were conducted to compare the behaviour of welded steel mesh and a TSL, when used in conjunction with rock bolts, in reinforcing strata with weak bedding planes and strata prone to guttering, two common rock conditions which exist in coal mines. It was found that while the peak load taken by the simulated rock mass with weak bedding planes acting as the control sample (no skin confinement) was 2494 kN, the corresponding value of the sample with 5 mm thick TSL reinforcement reached 2856 kN. The peak load of the steel mesh reinforced sample was only 2321 kN, but this was attributed to the fact that one of the rock bolts broke during the test. The TSL reinforced sample had a similar post-yield behaviour as the steel mesh reinforced one. The results of the large scale guttering test indicated that a TSL is better than steel mesh in restricting rock movement and thus inhibiting the formation of gutters in the roof.

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1. Introduction

Welded steel mesh has been successfully utilised in underground coal mines as a skin confinement medium for roof and rib strata for many years. It has, however, some intrinsic disadvantages such as installation is both time-consuming and labour-intensive, and it is a passive support that will not provide confinement until substantial rock displacement occurs. To meet the roadway development requirements to support future longwalls, the coal industry requires a significant increase in roadway development rates over that currently achieved. Thin spray-on liners (TSL) are an innovative rock support material which can be applied automatically so that increased roadway development rates can be achieved. In addition, they have many other merits over steel mesh, for example, they can be applied remotely so as to improve personnel safety and they generate resistance at small rock displacements. In order to compare the reinforcement capacity of welded steel mesh and TSL, various laboratory tests were performed.

Studies on steel mesh tests indicated that the behaviour of steel mesh is mainly a function of wire diameter, bolt spacing, mesh type, area of mesh loading, loading plate orientation, bolt tension, load surface and bearing plate size [1–3]. The mechanical properties of TSL, such as tensile strength, adhesive strength, shear and shear bond strength and flexural strength, have been studied extensively [4–10]. In addition, the rock mechanics research group at the University of Wollongong has conducted many laboratory tests to study the load bearing capacity of TSL, the ultimate strength of TSL and the tear behaviour of TSL [11–14]. Recent studies have found that the adhesive strength of TSL is inversely proportional to the square root of the liner thickness, and that rock properties and environmental conditions affect the adhesive bond of TSL [15,16]. In this study, the behaviour of welded steel mesh and a TSL in reinforcing strata with weak bedding planes and strata prone to guttering were investigated.

2. Strata prone to guttering

The aim of this experiment was to study the behaviour of a TSL and welded steel mesh in providing reinforcement to a rock mass prone to guttering. As implied above, tests were conducted on two samples named TSL reinforced sample and steel mesh reinforced sample respectively. Fig. 1 shows the sample preparation procedure. A timber mould (Fig. 1a) was firstly placed on the floor, and then concrete was poured into it to prepare triangular prisms. The triangular prisms were 200 mm in width, 400 mm in length

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(a) (b)

Fig. 1. Procedures for sample preparation, stages 1 and 2.

and 53 mm in height with acute and obtuse angles of 28° and 124° respectively. 16 mm holes were drilled through some of the triangular prisms so that threaded bar to simulate rock bolts could be grouted (Fig. 1b). The triangular prisms, 49 whole prisms and 14 half prisms, were layered into the steel frame to form a 400 mm × 400 mm × 800 mm rectangular concrete block. Welded steel mesh cut to size was bolted to the concrete surface. Bonding of the 5 mm thick fibre reinforced polymer sheet used the following process: an initial coat of resin was poured onto the concrete surface to form a bond to the concrete, and then a glass fibre sheet cut to size was placed on top of the resin and rolled into the resin. This process was repeated twice with a final cover of resin rolled into the last fibre sheet. Note that the resin and the fibre did not fully cover the concrete surface. This was done on purpose to guarantee that the polymer sheet did not touch the top or bottom platen during the loading process so that it was not loaded axially.

The tests were performed in a 500 t Avery compression testing machine. The load applied and the deformation of the centre point of the sample front surface was recorded by a 5000 kN load cell and a LVDT laser respectively. Fig. 2 illustrates the test set up.

The sample was forced to expand laterally as it was compressed at the top and bottom surface during the test on the steel mesh reinforced sample. Several triangular concrete blocks were observed to slip or move after only limited displacement, again illustrating the passive nature of steel mesh when used for skin confinement. The test terminated when the front surface of the sample was so close to the laser equipment that it may touch the laser equipment if the test continued. Note that the steel mesh did not fail at this stage. Block slippage or movement was also found in the test on the TSL reinforced sample, but it did not move or slip as much as in the steel mesh test. Debonding of the TSL sheet to the triangular prisms was observed in the test. One of the bolts broke during the loading process and the test was stopped for safety reason. As before, this test was halted without failure of the fibre reinforced polymer sheet.

The load versus lateral deformation behaviour of the two samples is illustrated in Fig. 3, the sudden drop in the TSL graph is a result of the failure of the bolts. Load fluctuations can be found in both graphs, which was a result of block slippage during the test. It is obvious that there are not as many fluctuations in the TSL

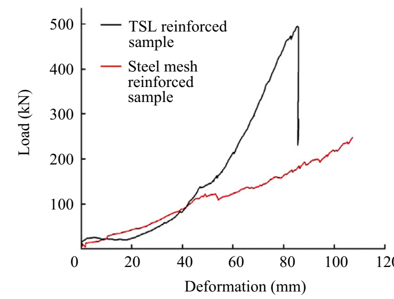
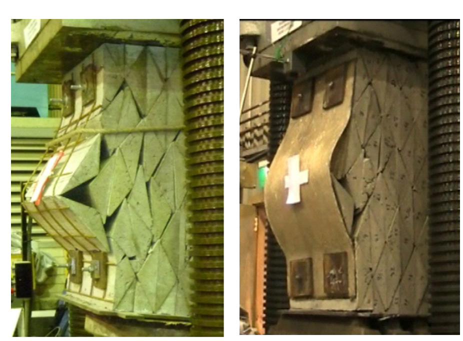


Fig. 3. Load versus deformation.

graph, indicating that the blocks did not slip to the same extent as in the steel mesh reinforced sample. The reason for this occurrence was that the adhesion at the interface of the concrete prism and the TSL restricted the movement of the blocks, while there was no adhesion between the steel mesh and concrete. It can be seen from Fig. 3 that the two samples behave similarly up to around 40 mm deformation, however, the TSL reinforced sample had a much stiffer load versus deformation relationship after 40 mm deformation. As neither the TSL sheet nor the steel mesh broke during the test, there was no point in comparing the maximum loads achieved in the two tests. It is worthwhile to note that the load of the steel mesh reinforced sample at a deformation of 80 mm is around 160 kN, while the corresponding value of the other sample is approximately 450 kN. Fig. 4 shows the displacement of each tested sample after 80 mm deflection. As noted in Fig. 4, it is obvious that the TSL restricts the development of guttering significantly better than steel mesh, a result of the bonded TSL acting as a composite with the substrate to immediately limit deformation and assist the strata to maintain integrity whilst substantial deformation is occurring.

Fig. 2. Test set up.



(a) Steel mesh (b) TSL

Fig. 4. State of guttering for the two tests after 80 mm deflection.

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