2013

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Publication Details

J. Nemcik, I. Porter and E. Baafi, Tear tests of glass fibre reinforced polymer skin spray-on liner, 13th Coal Operators' Conference, University of Wollongong, The Australasian Institute of Mining and Metallurgy & Mine Managers Association of Australia, 2013, 170-175.

TEAR TESTS OF GLASS FIBRE REINFORCED POLYMER SKIN SPRAY-ON LINER

Jan Nemcik, Ian Porter and Ernest Baafi

ABSTRACT: Current research into strata support automation in coal mine roadways requires development of a strong, tough and effective skin support that can be applied remotely. To investigate suitability of a glass fibre reinforced polymeric thin Spray-On Liner (TSL) numerous small and large scale samples were tested. These tests include; the tear load due to the lateral movement of TSL to fail in tear through the bolts installed in underground roadway roof, and the 'truser tear' due to the differential movement of the supported strata. The laboratory experiments suggested that a polymer based TSL can withstand substantial tear loads and despite the tear failure, the remaining TSL sheet can maintain strata support effectively. The tear strength tests were conducted using a standard 22 mm diameter steel bolt tearing the 5 mm thick polymer sheets reinforced with two or three glass fibre layers. The trouser tear tests were conducted with two and three layers of glass fibre reinforcement. The bolt tear tests indicated load bearing capacities in the range of 7.4 to 13.8 kN depending on the amount of reinforcement, while the trousers tear strength ranged from approximately 0.4 to 1.1 kN.

INTRODUCTION

During the ongoing TSL product development stage many small and large scale tests were carried out to evaluate the strength and failure modes of the TSL product itself and the rock-polymer composite material. These tests included tensile strength, three and four point bending strength, resistance to puncture, toughness and fatique tests of the polymeric product while the polymer-rock composite was tested for its reinforcement capabilities provided by the strong polymer to strata bond and the mechanical support of the strata by the polymeric sheet. These tests were reported in numerous publications (Lukey, *et al.,* 2008; Nemcik, *et al.*, 2009; Nemcik, *et al.*, 2011; Nemcik, *et al.,* 2012,). Two experiments were set up to investigate the tear loads when the rock bolt that pins the TSL to the strata tears through the TSL material and the 'trouser' tear of the TSL due to the differential movement of the supported strata.

BOCK BOLT-TSL TEAR TEST

The aim of this experiment is to determine the lateral loads on the rock bolt that tears through the glass fibre reinforced TSL. The basic principle of the tear test is shown in Figure 1. Several 5 mm thick polymer sheets 300x150 mm in size reinforced with two and three layers of glass fibre were prepared and cured overnight in the oven at a temperature of 60˚C. Preparation of the polymer sheets is shown in Figure 2. The edge of each sheet was clamped with steel brackets to enable anchorage of the sheet during testing. A 27 mm hole was drilled across the polymer sheet and a piece of standard Australian 22 mm diameter steel rock bolt was placed within.

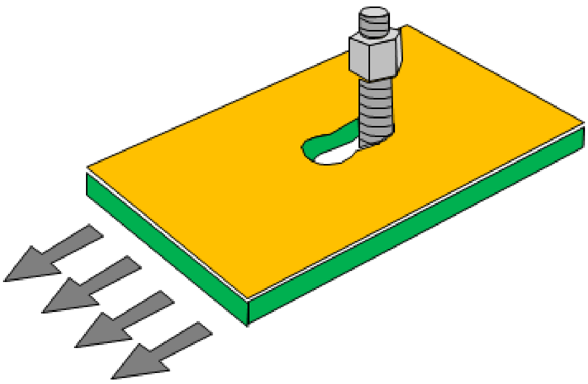

Figure 1 - Schematic diagram of the TSL tearing test

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Figure 2 - Preparation of the polymer based glass reinforced TSL

The TSL samples with the bolt in the hole were clamped into the 500 kN Instron servo-hydraulic universal testing machine and pulled appart at the rate of 5 mm/m while monitoring the applied load and displacements of each sample (Figure 3). In total, six samples were tested. Three samples were reinforced with two layers of glass fibre while the others contained three layers of glass fibre.

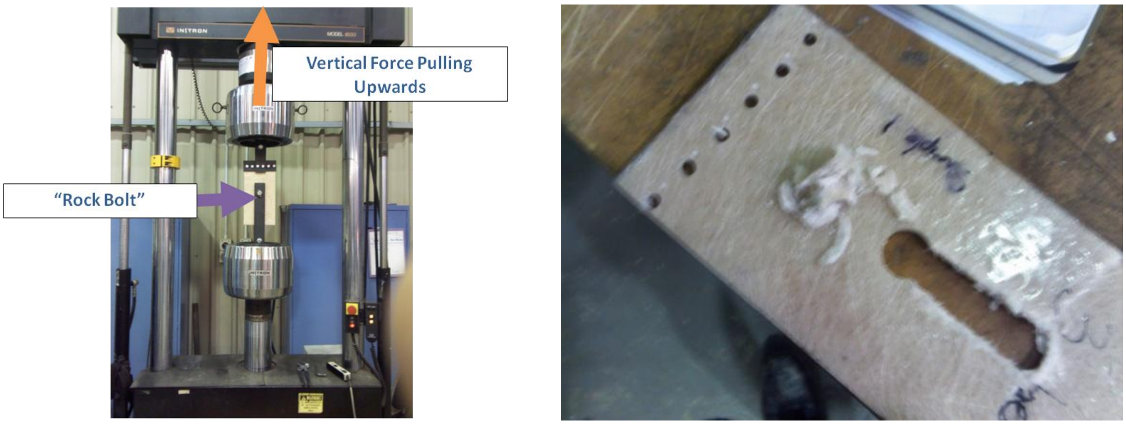

Figure 3 - The polymer sheet with steel rock bolt clamped into the 500 kN Instron servo-hydraulic universal testing machine and teared appart

The bolt tear resistance of samples that were reinforced with two glass fibre layers ranged approximately between 4 kN and 8 kN while the samples reinforced with three glass fibre layers tore at the applied load ranging from 6 kN to 12 kN (Figure 5). The measured tearing capacity of each polymer sheet versus displacement are graphed in Figures 4 and 5 while the results are detailed in Table 1.

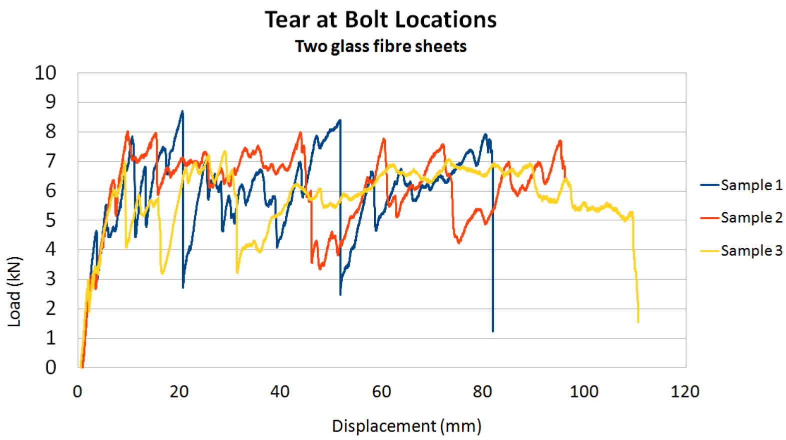

Figure 4 - The measured bolt tearing capacity of polymer samples reinforced with two glass fibre sheets

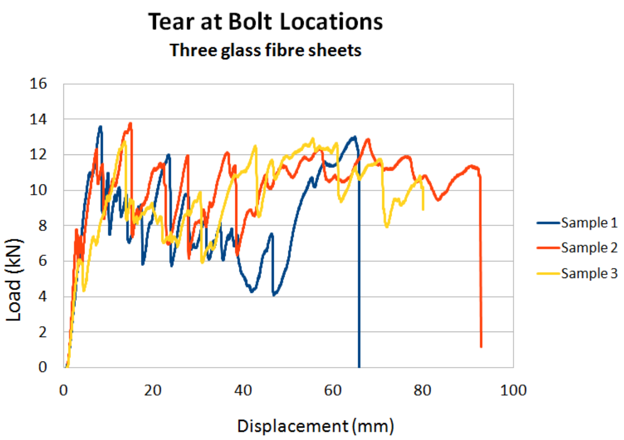

Figure 5 - The measured bolt tearing capacity of polymer samples reinforced with three glass fibre sheet

Table 1 - Results of the rock bolt - TSL tear

Number of glass sheets	Sample No.	Average sample thickness (mm)	Maximum applied load (kN)	Average allied load (kN)	Comments
2	1	5	8.7	6.0	Load fluctuation
2	2	5	8.0	6.3	Load fluctuation
2	3	5	7.4	5.9	Load fluctuation
3	1	5	13.6	8.4	Load fluctuation
3	2	5	13.8	10.4	Load fluctuation
3	3	5	12.9	10.0	Load fluctuation

The results indicate that the tested TSL-bolt tearing capacity may not be able to stop tearing action at high loads, however this is also the case for the currently used steel mesh that is readily deformable even at relatively low loads. If the bolt-TSL tear occurs in practice, its length would be shorter. Due to the toughness of the glass fibre reinforced TSL the tear would not compromise the TSL skin support substantially.

TROUSERS TEAR TEST

In accordance with AS 1683.12-2001, the trouser tear strength is the force required to propagate tear in the cut within the material divided by the material thickness. The basic principle of the trouser tear test is shown in Figure 6. Several polymer sheets 200x100 mm in size reinforced with two and three layers of glass fibre were prepared and cured in the oven at a temperature of 60˚C overnight. A 50 mm deep cut was prepared in each sheet to enable tear to propagate. The edges of each sheet were clamped with the steel brackets to grip each edge and pull in the opposite directions perpendicular to the polymer sheet to enable tearing of the material. The TSL samples were clamped into the 500 kN Instron servo-hydraulic universal testing machine and teared appart while monitoring the applied loads (Figure 7).

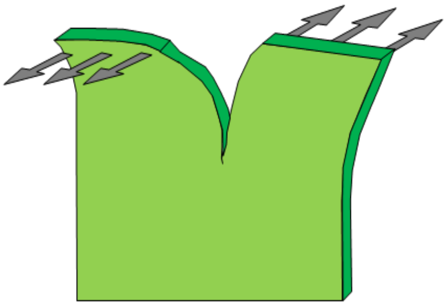

Figure 6 - Schematic diagram of the TSL tearing test

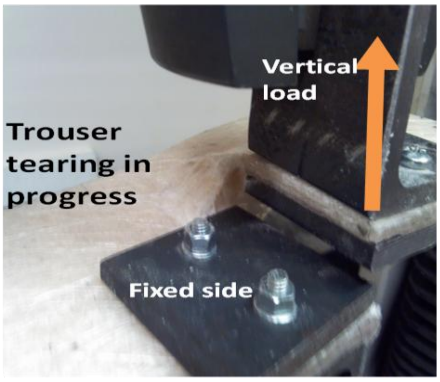

Figure 7 - TSL sample clamped in the 500 kN Instron servo-hydraulic universal testing machine and teared appart

In total, six samples were tested. At some stage the geometry of the polymer sample was modified to minimise tear in the wrong place. Three tested samples were reinforced with two layers of glass fibre while the others contained had three. The test results are shown in Table 2.

Table 2 - Results of the trouser tear tests

Number of glass sheets	Sample No.	Average sample thickness (mm)	Maximum applied load (kN)	Trouser tearing strength (kN/mm)	Comments
2	1	3.8	0.43	0.11	Teared
2	2	3.8	0.39	0.10	Teared
2	3	3.8	0.46	0.12	Teared
3	1	5.0	1.12	0.22	delaminated
3	2	5.0	0.96	0.19	delaminated
3	3	5.0	0.97	0.19	delaminated

The trouser tear resistance of samples that were reinforced with two glass fibre layers ranged from 0.10 to 0.12 kN/mm of sheet thickness while, as expected, the samples with three glass fibre layers tore at a higher load, which ranged from approximately 0.19 to 0.22 kN/mm. The measured tearing capacity of each polymer sheet versus displacement are graphed in Figures 8 and 9.

A delamination problem occurred in some tests where the TSL separated along the glass fibre layers as shown in Figure 10. This occurred due to the nature of laying the fibre during sample preparation. In ability of preparing samples with random fibre orientation may have contributed to the delamination problem. Delamination is unlikely to occur during TSL spray application. Futher tests need to be repeated with sprayed product.

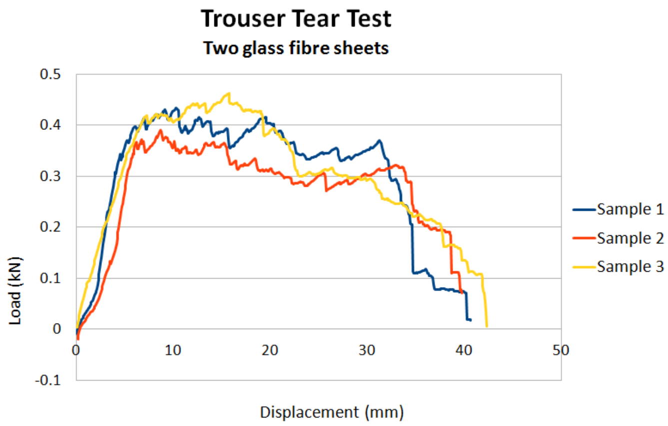

Figure 8 - The measured trouser tearing capacity of polymer samples reinforced with two glass fibre sheets

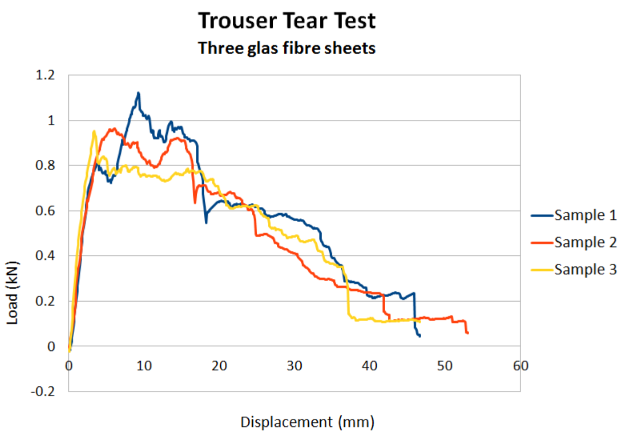

Figure 9 - Measured trouser tearing capacity of polymer samples reinforced with three glass fibre sheets

Figure 10 - Delamination along the glass fibre layers

DISCUSSIONS

The above tests indicate that the tested TSL material is tough and reasonably strong in tear. It should be noted that the samples were prepared in the laboratory under ideal conditions. The TSL was made by pouring the polymer into the mould furnished by several layers of glass fibre oriented parallel to the sheet surface. In practice, such sheet would be sprayed onto an uneven substrate with glass fibre that may be oriented in random directions. If the TSL is bonded well to the rock surface it will be subjected to the same differential deformations as would occur in the rock, resulting in tear. If the TSL bond fails, the TSL may not tear immediately but would provide normal confinement to the rock fracture surface generating skin reinforcement. Despite these differences the tearing tests indicate that the glass reinforced polymeric material is suitable to reinforce a relatively small roadway surface area located between the rock bolts making the tested TSL suitable for the mine roadway skin reinforcement.

No significant dynamic loads are experienced in most Australian coal mines. This has been confirmed using countless extensometry measurements that show the gradual strata movement with relatively small displacements until a predictable convergence and audible strata sound indicating imminent roof collapse. During the normal working life of a coal mine small differential displacements of the roadway skin may occur and can cause a bolt-TSL tear or a small trouser-type tear similar to the above tests. Under normal conditions this type of failure should not cause a significant problem as the remaining TSL adjacent to the tear would continue to support the roadway skin. During the collapse of mine roadway significant TSL tear could occur however, this problem would not be relevant as the TSL is not designed to control the overall stability of strata.

CONCLUSIONS

This study investigated the resistance of 5 mm thick glass fibre reinforced TSL to tear due to the differential movement of the steel bolt that restrains the TSL from lateral movement, and trouser tear that can occur during differential movement of the jointed strata. The tests indicate that the 5 mm thick TSL reinforced with three glass fibre sheets is capable of resisting bolt tear loads of up to approximately 14 kN and trouser tear of up to 1.1 kN. A delamination problem occurred at some of the trousers tear tests, where the TSL separated along the glass fibre layers. This occurred due to the nature of laying the fibre during sample preparation. The tearing capacity of the *in-situ* TSL may increase when the polymer and the mine roadway skin form a composite layer. Further tear tests of the sprayed TSL are recommended to provide more accurate data for future assessment of the TSL as a composite material as an alternative method to the current methods of the mine roadway skin support in Australian coal mines.

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