Ground Support 2023 – J Wesseloo (ed.)

doi:10.36487/ACG_repo/2325_30

Importance and development of pre-tension on bolt support systems: implications to hanging wall beam stability

MN Masitise *Mohlalefi Engineering, South Africa*

M Muzavazi *Mohlalefi Engineering, South Africa*

Abstract

Stratified and often discontinuous excavation roofs or hanging walls have traditionally produced challenges in mining because of the condition of the hanging wall beam. A zone above the hanging wall exists where the strata forming the hanging wall beam are in tension, which tends to dilate, buckle, and delaminate, eventually falling out if not clamped. Introducing tensioned tendons in this system helps immobilise the individual blocks and clamp the strata, thus improving the stability of the hanging wall beam. There are different systems of tendon or bolt installations. Tensioned bolts are more efficient because a more stable beam can be built with the same bolt by applying a larger installed tensile load. Active pre-loads modify roof behaviour by dramatically reducing bed separation and delamination clamping together with thinly laminated roof beds, forming thicker beams and eliminating bed separations, thus restoring the structural integrity of the roof. The performance of the equipment used to install the roofbolts affects the quality of bolt installation. The first challenge is achieving the desired pre-tension load during installation, and the second is the logistics of generating the required torque using handheld equipment in some cases. Torque wrenches overestimate the pre-tension loads because of frictional losses when the bolt head is tensioned against the plate. Steel wire strand bolts encapsulated in resin (flexible bolts) generally have a high load-bearing capacity and are perfect candidates for pre-tensioning. More than 80% of the strand-type bolts used worldwide are pre-tensioned to approximately 15 t or more, and the growth of this practice provides circumstantial evidence of effectiveness. Mohlalefi Engineering developed a patented, efficient torque multiplier system with a dual-socket configuration to allow the generation of pre-tension loads up to 20 t for strand bolts and by extension arresting pre-tension decay through the provision of a primary stationary nut–socket interface (anti-spin mechanism). The system can be used on small drill rigs with an output spindle torque of 80 Nm, as well as in modern hydraulic drill rigs that produce output torques between 240 and 400 Nm. Following underground installations carried out with the dual-socket torque multiplier at Mototolo platinum mine, in Limpopo province, South Africa, it was possible to pre-tension flexible bolts to 15 t using a conventional bolter. Destructive lab tests were conducted on the Mohlalefi Anchorflex, which aimed to determine the overall system resistance and safe working load. The resistance achieved ranged from 299.6–300.3 KN and all strands were threaded at both ends and held in place by nuts. The failure mode was strand breakage in all cases. The Mohlalefi torque multiplier can achieve pre-tension loads of up to 15 t on flexible bolts with a minimum breaking load of 30 t. A comparison of the input force or pressure with the torque achieved gives a clear indication of the efficiency of the system.

Keywords: *pre-tension, anti-spin, torque multiplier, beam stability, cable bolts*

1 Introduction

The principal objective of any roof support system is to support the mine roof as soon as possible by assisting the rock mass in supporting itself. This objective has led to pre-stressing roof support systems so that an immediate active support load can be applied to the mine roof (Rataj 2002). The active roof loading provided by pre-stressing closes separations in the roof and increases the frictional restraint along the bedding, joints, and other fracture planes, thereby enhancing beam construction. Pre-tension is critical in providing active support for controlling roof sagging and bedding plane slippage in underground mines (Rataj & Thomas

1997). However, the optimal amount of pre-tension required to achieve effective ground control is an important determinant of support performance. Applying excessive pre-tension may cause support element failure, whereas insufficient pre-tension is ineffective in preventing deformation and roof fall/failure.

The pre-tensioning of the roof and some cable bolts is achieved by tightening the end nut to a predetermined torque. Although this has been an effective means of pre-tensioning conventional roofbolts, this approach is more problematic with cable bolts because the wire strands twist when torque is applied and can untwist when the torque is removed, resulting in a decay of the achieved tension. Nut tightening to achieve pre-tension is also subject to significant frictional losses, which further reduces the efficiency of this approach. These factors lead to high variability (up to 45%) in the achieved pre-tension load (Barczak et al. 2003).

1.1 Flexible roofbolts (cable bolts) and pre-tensioning factors

A high strength steel cable bolt was originally developed by Barret, Fuller and Partners in 1993 and presented at the 12th International Conference on Ground Control in Mining (Fuller & Grandy 1993). The development of the original flexible roofbolt originated from the idea of using a multiwire, single strand to take the place of a rigid bar-type roofbolt. The outer diameter of the cable is threaded and engaged with a threaded nut, similar to the rigid bar-type roofbolt.

The performance of the equipment used to install roofbolts impacts the quality of bolt installation (Barczak et al. 1993). The first challenge is achieving the desired pre-tension load during installation and the second is the logistics of generating the required torque using handheld equipment in some cases. Torque wrenches overestimate the pre-tension loads because of frictional losses when the bolt head is tensioned against the plate.

Steel wire strand bolts encapsulated in resin (flexible bolts) generally have a high load-bearing capacity and are perfect candidates for pre-tensioning. More than 80% of the strand-type bolts used worldwide are pre-tensioned to approximately 15 t or more, and the growth of this practice provides circumstantial evidence of effectiveness (Barczak et al. 1995).

1.2 Torque multiplier concept and dual-nut system

Mohlalefi Engineering developed a patented efficient torque multiplier system (Patent Claim Priority GB 2006483.8, PCT/IB2021/053631) to allow the generation of pre-tension loads up to 20 t for strand bolts. The dual-nut system also provides an anti-spin function which prevents cable recoil after tensioning, thus eliminating pre-tension degeneration. The system may be used on small, manually operated drill rigs with a spindle output torque of about 80 Nm and the torque multiplier amplifies the output torque of the spindle to more than 10 times. The system can also be used on modern hydraulic drill rigs that produce a spindle output torque of between 240 and 400 Nm to achieve even higher torque outputs. The torque multiplier employs a dual-socket system, where the primary socket is fixed on the cable's outer nut while the secondary socket engages the cable's inner nut independently to tension the cable. The primary socket provides the stationary interface for the counter torque. Figures 1 and 2 show the nut arrangement, as well as the interface with the torque multiplier.

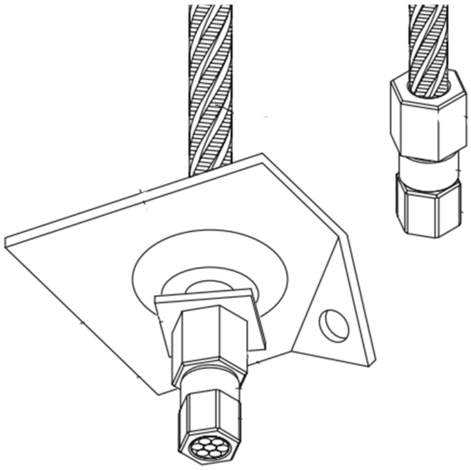


Figure 1 Diagrammatic representation of the Mohlalefi dual-nut, high pre-tension, anti-spin cable bolt

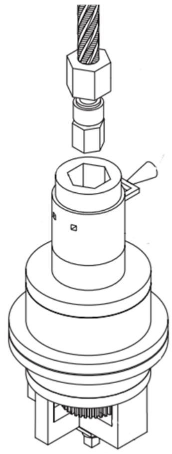


Figure 2 Diagrammatic representation of the Mohlalefi dual-socket, high pre-tension, anti-spin torque multiplier

Figure 3 depicts how the dual-nut cable bolt is configured before and after pre-tensioning using the dual-socket torque multiplier. The secondary nut travels along the cable bolt (away from the primary nut) until the desired pre-tension is achieved. The primary nut is fixed on the cable bolt and provides the rigid attachment point for holding the cable bolt steady and preventing the cable bolt from rotating.

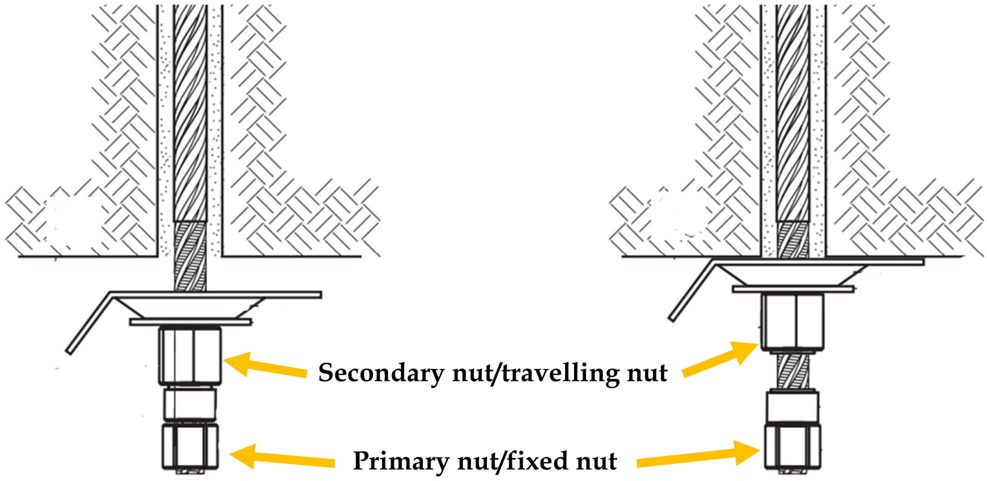


Figure 3 Representation of the Mohlalefi dual-nut cable bolt before and after tensioning

2 Methodology

2.1 Lab pull tests: cable and nut strength tests

The Mohlalefi flexi bolts underwent independent destruction in tension tests at the Council for Science and Industrial Research (CSIR) testing laboratory, per our request. The machine used a 4,448 kN Mohr & Federhaff tensile testing machine. The assemblies were installed in the Mohr & Federhaff tensile testing machine using suitable fittings, as shown in Figure 4. A gradually increasing tensile load was applied to each assembly until failure in tension occurred.

Figure 4 Compact strand assembly installed in a test machine at the CSIR laboratory

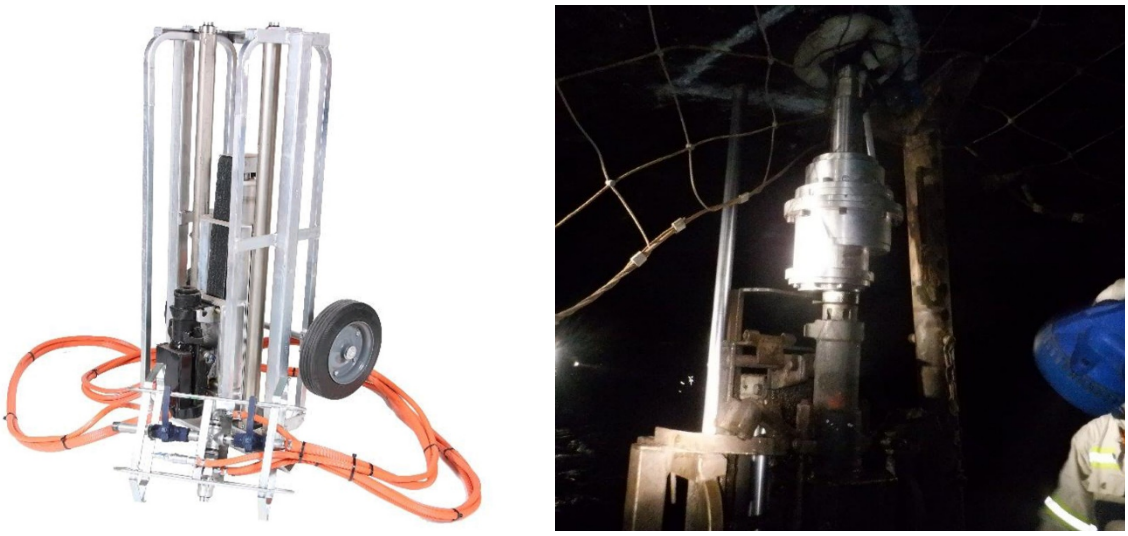
2.2 Underground tests: cable pre-tensioning

Figure 5 shows the 4 m long cables assembled with a collapsible load indicator for the required pre-tension load. In this case, the pre-tension load indicator is 15 t.

Figure 5 The 4 m long Mohlalefi dual-nut, high pre-tension cable bolts before and after tensioning with the torque multiplier

The cables are installed using the torque multiplier mounted on an Autorock Drill Rig machine. A 38 mm hole, 4 m deep was first drilled and then 4 m long cable was manually inserted, and the torque multiplier was attached on the Autorock Drill Rig. The torquer multiplier was then used to engage the dual nuts and tension the cables, as shown in Figure 2.

Figure 6 shows the Autorock Drill Rig configuration while the second image shows the Autorock Drill Rig with the torque multiplier attached in an underground installation.



(a) (b)

Figure 6 (a) Autorock machine; (b) Autorock machine with the dual-socket torque multiplier attached

In Figure 7, the dual-socket torque multiplier unit is shown facing upwards, highlighting the dual-socket system with both the inner and outer socket. The two sockets rotate in opposite directions when the torque multiplier is driven. The Autorock driving spindle is attached to the base of the dual-socket torque multiplier.

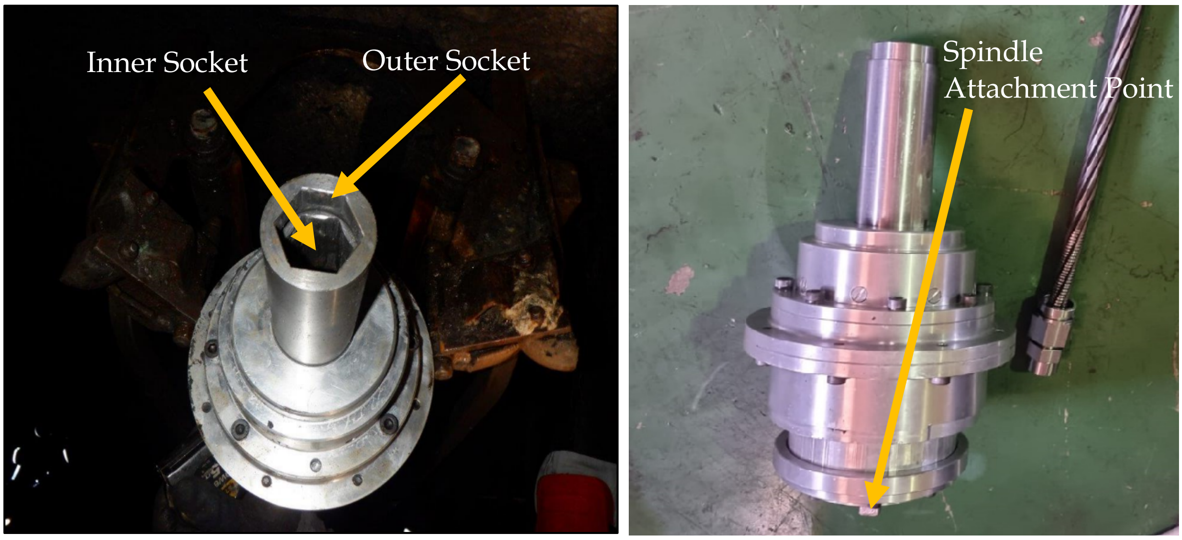


Figure 7 Dual-socket torque multiplier mounted on the Autorock machine

3 Results

Table 1 shows the results of the lab tests carried out on the 18 mm cable strand. The average load achieved on the six tests was 302.8 kN with a standard deviation of only 10.3 kN. Figure 8 shows the general mode of failure of the strand. Figure 9 shows a graphical overview of how the results were distributed.

Table 1 Test results of the 18 mm compact strand DIN405 thread assemblies

Test no.	Maximum load carried (kN)	Mode of failure
1	321	The cable strands fractured as shown in Figure 8.
2	298	
3	298	
4	297	
5	309	
6	294	
Mean	302.8	
Standard deviation	10.3	

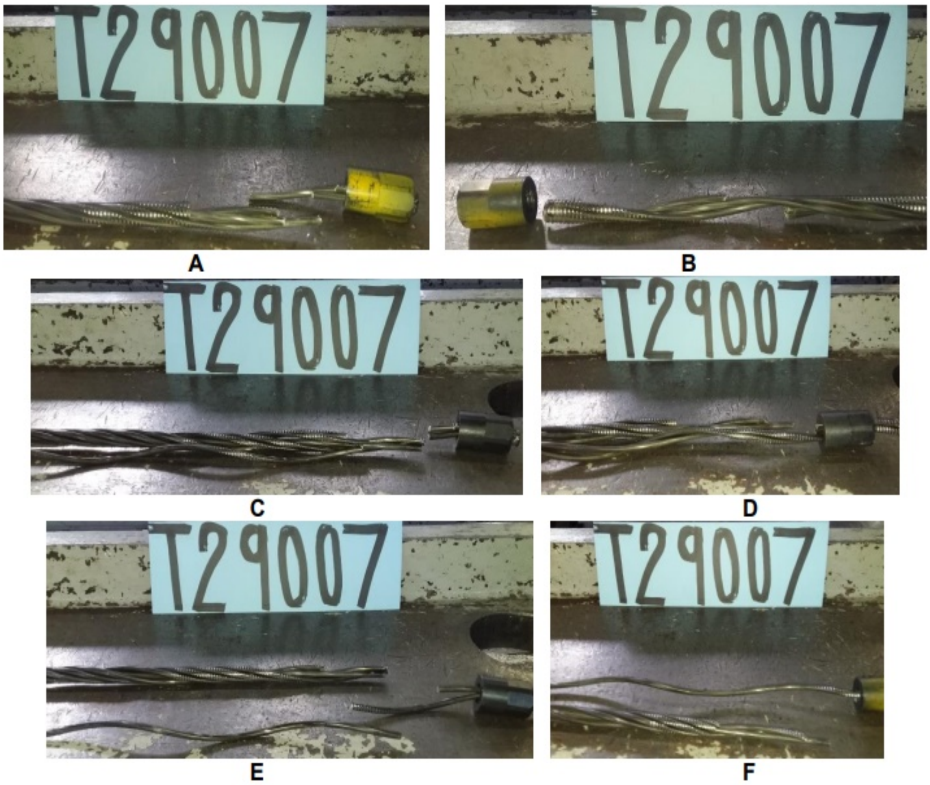


Figure 8 General mode of failure on cable bolts through tensioning

Test Nr.:	1	2	3	4	5	6
Maximum force :	321 kN	298 kN	298 kN	297 kN	309 kN	294 kN

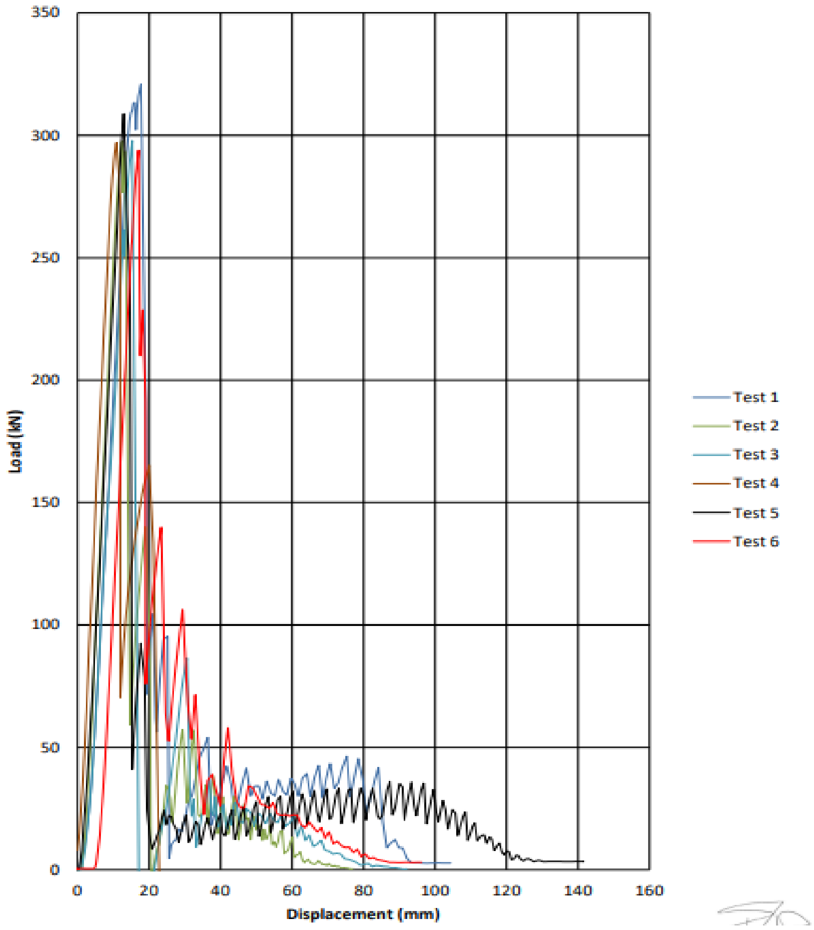


Figure 9 Graphical representation of the cable bolt lab test results

The results obtained from the underground torque tests postulated that the torque multiplier can achieve pre-tension loads of 15 t in all installations. The results were shown through the load indicator fitted on the cable bolts. Figure 10 below shows the 2 mm groove load indicator before collapsing and Figure 11 shows three installations with a collapsed 15 t load indicator after pre-tensioning.

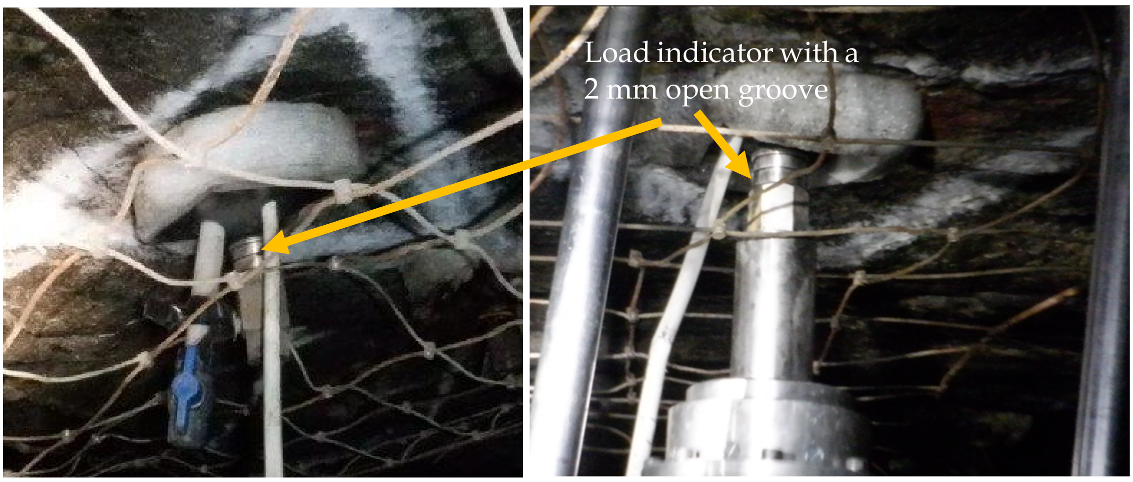


Figure 10 Uncollapsed 15 t load indicator with an open grove before pre-tension

Figure 11 Collapsed 15 t load indicator after pre-tension

4 Conclusions

It can be concluded that the Mohlalefi cable bolt (from an 18 mm compact strand) can achieve a load-bearing capacity of 300 kN. Moreover, the dual-socket torque multiplier can achieve pre-tension loads of up to 15 t on cable bolts using a conventional hand operated bolter (Autorock). A comparison of the input force or pressure with the torque achieved gives a clear indication of the efficiency of the system in multiplying the input torque and arresting pre-tension decay. It can also be concluded that the cable bolts can be tensioned without any rotation of the cable bolt (anti-spin effect), while the cable bolt is held steady by the primary/fixed nut of the dual-nut system.

Acknowledgement

We acknowledge Anglo Platinum, South Africa, Mototolo mining operations in Limpopo province, rock engineering staff and management for their support in conducting the underground tests. We would also like to acknowledge the CSIR, Auckland Park, Johannesburg laboratories for their support in the research and availing their tensile test lab facility to us.

References

Barczak, TM & Gearhart, DF 1993, *Engineering Methods for Design and Employment of Wood Cribs*, U.S. Bureau of Mines Information Circular 9361, Washington.

Barczak, TM & Gearhart, DF 1995, 'Renewed interest in prop supports as a replacement for wood cribs', in SS Peng (ed.), *Proceedings, 14th International Conference on Ground Control in Mining*, West Virginia University, Morgantown, pp. 149–158.

Barczak, TM, Bower, J & Chen, J 2003, 'Pumpable roof supports: developing design criteria by measurement of the ground reaction curve', in SS Peng (ed.), *Proceedings of the 22nd International Conference on Ground Control in Mining*, West Virginia University, Morgantown, pp. 283–293.

Fuller, PG & Grandy, PO 1993, 'Flexible roof bolts: a new concept for strata control', in SS Peng (ed.), *Proceedings of the 12th International Conference on Ground Control in Mining*, pp. 24–34.

Rataj, M 2002, 'Improvement in pre-tensioning of strand bolts in Australian coal mines', in SS Peng, C Mark, AW Khair & K Heasley (eds), *Proceedings, 21st International Conference on Ground Control in Mining*, West Virginia University, Morgantown, pp. 145–149.

Rataj, M & Thomas, R 1997, 'New methods, and technologies of roof bolting in Australian coal mines', in SS Peng (ed.), *Proceedings, 16th International Conference on Ground Control in Mining*, West Virginia University, Morgantown, pp. 149–157.