DYWIDAG-SYSTEMS INTERNATIONAL

DSI

DEVELOPMENT OF HI-TEN BOLT IN AUSTRALIAN COAL MINES

Mietek Rataj, Research & Development Manager
DYWIDAG-Systems International Pty Limited (DSI)
Newcastle, New South Wales, Australia

ABSTRACT

Pre-tensioned strand bolts (resin grouted cable bolts) developed during the last decade are very common now in Australian coal mines. The strand bolt consits of a cable stiff enough to be installed like a solid bolt, yet flexible enough to be used in large lengths. As its installation is much easier and faster when compared to conventional (cement grouted) cable bolts it is also used as a primary support.
These bolts are pre-tensioned to significant loads and that proved to increase the efficiency of ground support.

One of the important achievements was development of the bolt fitting which significantly reduces bleed of load during the tensioning process. The fitting consists of a special barrel housing a centralising rim which keeps the cable in the centre of the barrel which allows for proper alignment of the wedges even if the plate tilts during the tensioning.

Historical development of the strand bolt as well as the tensioning systems is outlined

INTRODUCTION

Cable bolts in Australia have been used for rock reinforcement in underground metalliferous mines from 1970's and in coal mines from early 1980's. The cables were cement grouted and mostly un-tensioned. Limited load only was applied against the barrel and wedges to make sure the wedges were set and the roof plate was tight against the rock.

In the coal mines, some of the cable bolts bottom sections were debonded and up to 10 tonnes of pre-load was then applied. More often pre-tensioning was used for installation of sling type cable bolt support. Again, relatively low load was applied to the spliced cable bolt tails. Typically, applied tension was in a range of 5 to 10 tonnes.

Introduction of Strand Bolts ie. resin anchored cable bolts in early 1993 and their relatively simple method of at the face installation during the normal bolting cycle initiated development of support pre-tensioned to significantly higher loads.

The existing tensioners were not suitable for pre-tensioning of the Strand Bolts because their strand diameter (23.5mm) was significantly larger than the conventional cable bolt strand (15.2mm). Also the conventional cable bolt tensioners required relatively long bolt tail (at least 300mm) to operate. Since the Strand Bolt cable is relatively stiff it was important that in many areas their tails were as short as possible.

Development of new type tensioners was therefore necessary and bleed off tension, unavoidable with barrel and wedge, became an issue.

FLEXIBOLT

Development of pre-stressed strand bolts ie. resin grouted cable bolts was initiated in Australia by introduction of Flexibolts in 1993 (Fuller et al, 1993).

The Flexibolt is a high strength (about 60 tonnes) strand of 23.5mm diameter. It has a rolled thread on the collar end with a barrel and wedge like fitting placed above a drive nut (Figure 1). Installation is virtually identical to that of roof bolt, with the nut being tightened to obtain a bolt tension. High torque tensioning through the nut is not possible due to the limited torsional stiffness of the strand as well as the presence of the barrel/wedge system. Depending on torque output of the typical bolting equipment used, Flexibolt could be pre-stressed with 2 to 5 tonnes of load.

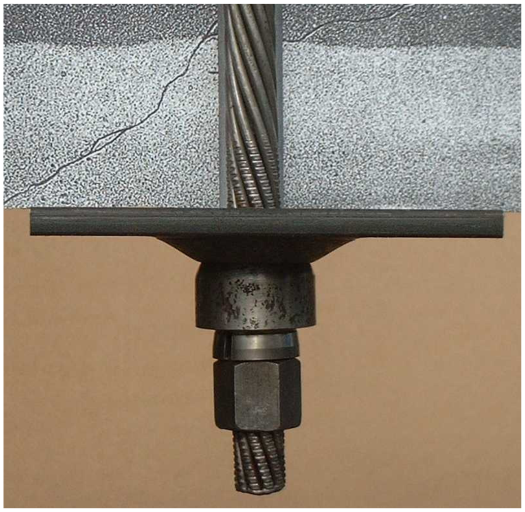

Figure 1 - Flexibolt

It was anticipated however that pre-tensioning of strand bolts to loads significantly higher than 5 tonnes may have a great potential in strata reinforcement. Installation procedure of these type bolts ie. anchoring them with fast curing resin as opposed to being cement grouted made the pre-tensioning procedure relatively simple. There was another very important factor which enhanced the introduction of high load bolt pre-tensioning. This was the possibility of the installation of Flexibolts during the normal bolting cycle by miner mounted rigs or hand held bolters. It allowed the bolts to be installed and pre-tensioned before the roof had chance to deform. It was very quickly realised that pre-tensioning of bolts is most beneficial when applied as early as possible in the mining cycle. To increase the pre-loading level of the Flexibolts, first hydraulic tensioner suitable for this type bolt was developed in 1996. Load capacity of this tensioner was 30 tonnes which happen to be the most optimum level from the availability of the hydraulic components (cylinders and pumps).

This tensioner allowed the bolt head assembly on the bolt to be pulled away from the roof. The tension was then locked in the bolt by threading a supporting nut up against the roof plate. The nut was positioned on a locker (threaded hollow bar) placed on bolt between the plate and barrel as shown in Figure 2.

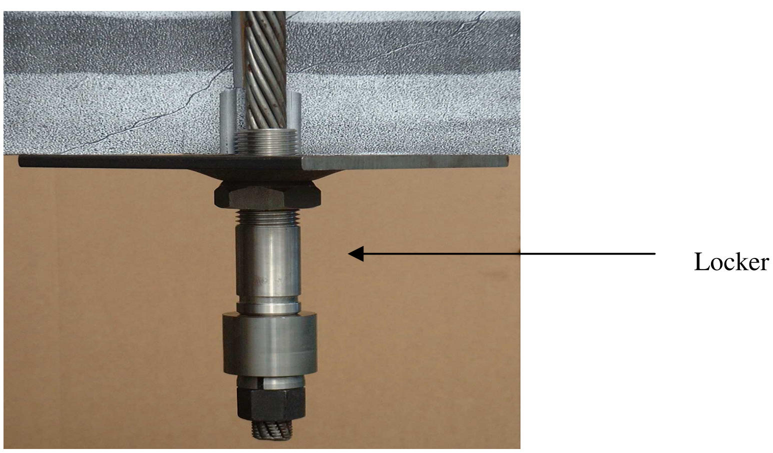

Figure 2 – Flexibolt Pre-Tension – Nut and Locker

In spite of a number of down sides which include the length of the bolt tail protruding from the roof (about 300mm) relatively high cost of the locker and cumbersome application of the tensioner, this system was accepted at a number of mines. The first trial results in terms of strata control were very encouraging. The pre-tensioned Flexibolts either delayed the outset of abutment loading induced roof movement or dramatically slow ongoing roof displacement (Rataj et al, 1997 and Fuller et al, 1997).

Soon after that, an improved system for pre-tensioning of Flexibolts was developed. The new system replaced the nut of the Flexibolt with a flat sided threaded cone (Figure 3). During installation, the flat cone was first used as a drive head to rotate the cable. To tension the bolt, especially designed tensioning unit of 30 tonne capacity, consisting of two hydraulic cylinders was used. It was placed over the end of the strand bolt and rotated through 90 degrees so as to lock the tapered cone in the main plate of the tensioner. The tensioner pulled the end of the cable away from the roof and at the same time pushed the cone and collar against the roof plate.

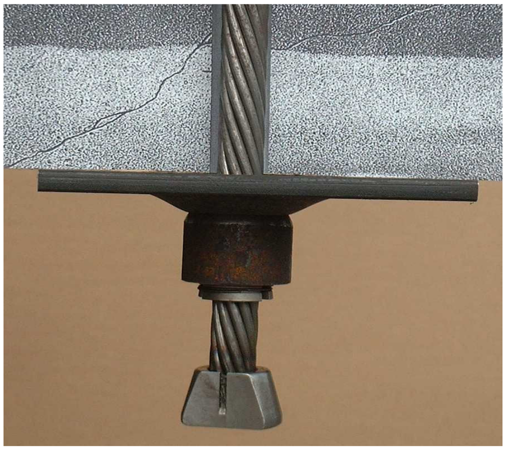

Figure 3 – Flexibolt Pre-Tension – Flat Cone

This system was less expensive and more user friendly. Again, when used at Central Colliery it allowed to reduce support density and improved stability of Longwall installation roadway (Rataj et al, 1998).

HI-TEN STRAND BOLT AND TENSIONER

A major breakthrough in the pre-tensioning system was achieved with development of Hi-Ten Strand Bolt System. The cable was similar to the Flexibolt but it was not threaded (Figure 4).

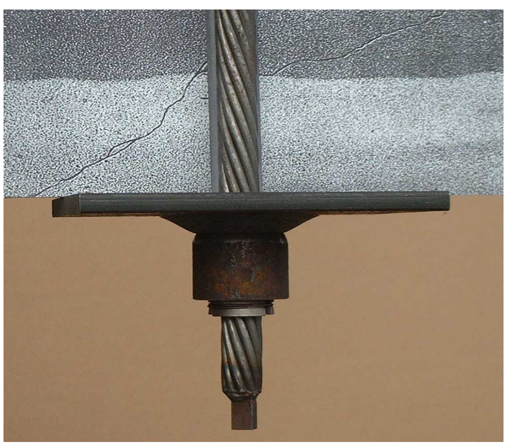

Figure 4 – Hi-Ten Strand Bolt

Hi-Ten Bolts, similarly to Flexibolts were point anchored only but later on, their full encapsulation was also developed. The end fitting of the Hi-Ten Bolt consisted of special barrel and wedges. The special barrel was designed to reduce bleed off tension. The tensioner still consisted of double hydraulic cylinders, but incorporated a very simple method of attaching and removing the tensioner to and from the cable.

This tensioner was subsequently modified to a single cylinder. This unit (Figure 5) is currently used. It is very simple to operate. Once fitted over the end of the cable it will engage automatically. The required bolt tail length is only 70mm. Jack load of up to 30 tonnes can be applied. To remove the unit after pre-tension of the cable a rope has to be pulled down to disengage the cable grippers. The tensioner can be operated by hand as its weight is about 12kg. It can be powered by compressed air-hydraulic pump as shown in Fig 5 or it can be connected to a hydraulic system of various mining machinery.

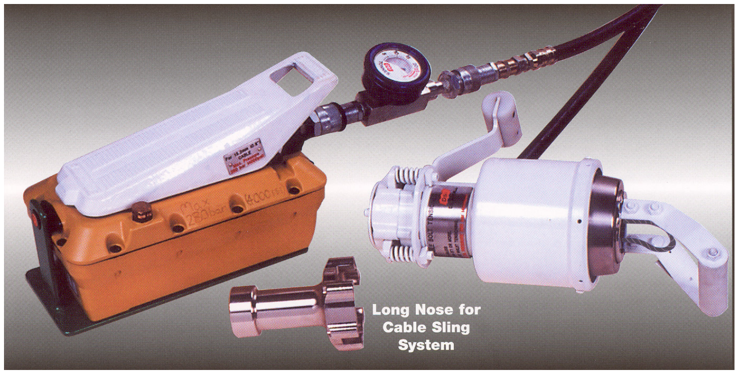

Figure 5 – Hi-Ten Strand Bolt Tensioner

Application of Hi-Ten Bolts proved very beneficial in various geological conditions of Australian coal mines. It's success can be attributed to the fact that the long tendon support can be installed at the face during a normal bolting cycle and it can be pre-tensioned before roof deformation takes place.

Currently over 80% of Australian coal mines use strand bolts which are pre-loaded mostly up to 20 to 25 tonnes.

BLEED OF TENSION

Bleed of tension is one of the major problems encountered during pre-loading of Strand Bolts. It is highly undesirable for a number of reasons. Firstly, the loss of tension largely goes unnoticed and the actual pre-load achieved may be well below the expected one. Secondly, when the loss of tension is realized often significant overload must be applied to compensate for the losses. The application of high load and its subsequent reduction causes undesirable rocking of the immediate roof. This may induce rock fractures around the bolt plate if the immediate rock is weak. Also, the intended pre-tension of the bolt cannot be achieved if the "over tension" required is above the load capacity of the hydraulic jack.

Using barrels and wedges to lock the pre-load in the cable, some loss of tension is inevitable. It will always occur since on the release of the tensioner pressure, the wedges will be drawn into the barrel which will allow for some relaxation of the load. The undesirable draw-in of the wedges in to the barrel is caused by number of factors and some of them can be engineered out to minimize it. The major factor affecting the level of lost tension is tilting of the bearing plate during tensioning. Plate tilting is caused by one-sided crushing of rock ridges and/or pushing of roof mesh into a cavity of uneven roof (Figure 6).

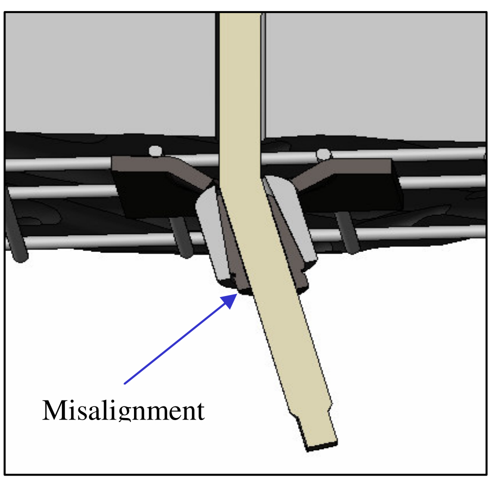

Figure 6 – Strand Bolt – Conventional Barrel

As shown in Figure 6 the collar tilts together with the tilted roof plate being joined together through contact friction. It causes bending of the cable as the cable is being pulled always in a direction perpendicular to the face of the collar. Subsequently wedges cannot be pushed deep enough into the barrel. When the jack load is released, the draw-in of wedges is significant and causes excessive return of the cable and its relaxation. Apart from the undesirable loss of pre load, the eccentric position of the cable in the barrel causes a severe misalignment of wedges which may affect performance of the fitting.

To minimize the loss of tension in the cable during pre-tensioning the Hi-Ten Strand Bolt is used with a special barrel. The new barrel has a specially designed centralizing rim. The rim's inside diameter is only slightly larger than outside diameter of the cable which allows the cable to remain centralized in the barrel when the plate tilts as shown in Figure 7. This system ensures the maximum depth of the wedges in the barrel and proper alignment of the wedge segments.

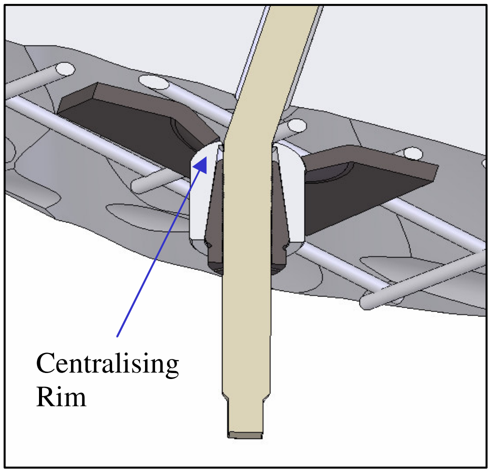

Figure 7 – Strand Bolt – Rimmed Barrel

Other features of the DSI Tensioner to reduce the loss of tension include a tight fitting of the barrel in the nose plate. This ensures the central position of the cable in the barrel particularly during tensioning of inclined bolts. Also, full jack load is applied to the barrel with a spring applying partial loading to the wedges (shown in Figure 8) as opposed to systems where the full jacking load is applied to the wedges only or to the barrel with a fixed spacing nose cone loading the wedges with extremely variable load depending on dimensional variances of all the mating components (D J Hutchinson et al, 1996).

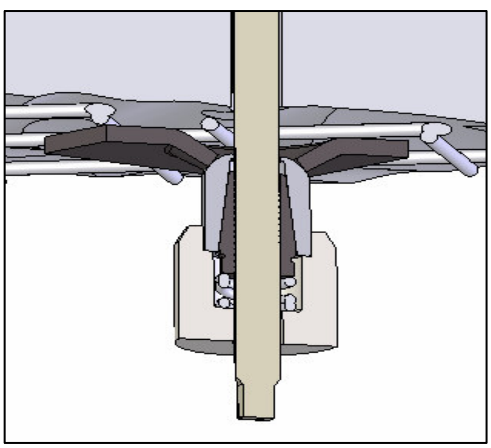

Figure 8 – Tensioner Nose Plate and Spring

The loss of tension also depends on the cable free length – the shorter it is the greater the loss will occur since the reduction of strain due to the movement of wedges is more significant when compared to a strain of short cable rather than that of a long one.

HI-TEN BOLT SYSTEM PERFORMANCE

In order to determine the effectiveness of the Hi-Ten Bolt tensioning system in terms of reduction of the bleed off tension due to plate tilting, comparable test was carried out using a conventional and rimmed barrels. The plate was allowed to tilt up to 10^{o} (being a typical value) and 3.5m cable free length was pre-loaded to 20 tonnes.

Losses of tension for the system with conventional and rimmed barrels are compared in Table 1.

Table 1 – Typical Losses of Tension of Systems with Conventional and Rimmed Collars

	Pre-Load (Tonnes)	Residual Load (Tonnes)	Percentage Loss of Load (%)
Conventional Barrel	20	9.6	52
Rimmed Barrel	20	14.8	26

The Table 1 shows that for 20 tonne pre-load in typical conditions the rimmed barrel system allows for 26% loss of pre-tension but it still ensures over 50% higher cable residual load when compared to system with the conventional barrel.

SUMMARY

Significant development of Strand Bolt systems including pre-tensioning methods and equipment took place in Australia within the last decade. It culminated with development of the Hi-Ten Strand Bolt System.
Major features of this development are:

- Long tendon support can be practically installed at the face as a primary support during normal bolting cycle i.e. before roof deformation takes place
- Tensioning system is efficient and user friendly and elimates excessive rocking of roof strata achieved mainly by introduction of an innovative barrel with centralising rim

Currently pre-tensioned strand bolts are being used by over 80% of Australian coal mines for primary and secondary ground support.

REFERENCES

1. Fuller, P.G. and O'Grady, P., (1993) "FLEXIBOLT Flexible Roof Bolts: A New Concept for Strata Control", 12th International Conference on Ground Control in Mining, Morgantown, West Virginia, USA.

2. Rataj, M. & Thomas, R. (1997). New methods and technologies of roofbolting in Australian coal mines. 16th International Conference On Ground Control In Mining, West Virginia, Morgantown, USA.

3. Fuller, P.G., Bijelac, M. Hulls, I.R. and Rochford, T. Prestressing of Strands to Improve Cable Performance. ACARP Project Report C4025, December 1997.

4. Rataj, M. & Hanson, C. & Frith. (1998). Innovative roofbolting technologies in Australian Coal Mines. International Conference Geomechanics/Ground Control in Mining and U/G Construction, Wollongong, Australia, 14-17 July 1998.

5. Hill, D. Application of 50 to 60 tonne cable pre-loads to roof control in difficult ground conditions. ACARP Project Report C8019, March 2001.

6. Hutchinson, D.J. and Diederichs, M.S. "Cablebolting in Underground Mines" Published by BiTech Publishers Ltd. Richmond, British Columbia, Canada 1996.