2013

Improvements in long tendon support with pumpable resin

Tom Meikle
Minova Australia

Stephen C. Tadolini
Minova USA

Robert Hawker
Minova

Daniel Pollack
Minova Australia

IMPROVEMENTS IN LONG TENDON SUPPORT WITH PUMPABLE RESIN

Tom Meikle[1], Stephen C Tadolini[2], Robert Hawker[3] and Daniel Pollack[4]

ABSTRACT: Long tendon support systems provide several challenges when used as part of the secondary or primary support cycle. A two-component pumpable resin, Carbothix, has been in development for use with self-drilling rock bolts. Many of the attributes of this new resin system make it ideal for grouting long tendon support systems. While neat Portland cement grouts or polyester resin capsules have been used with long tendon support systems for many years, two-component pumpable resin systems overcome many of the shortcomings in these systems. The two-component systems dramatically improve the set-time to enable mining face advance with fewer delays, enable longer pumping distances, improve quality control, and enhance load transfer mechanisms. This paper describes the key benefits associated with a new pumpable resin and details the Coal Services Health/Workcover atmospheric testing results and cable load testing completed to date. It also details the results of the Australian mine site trials and the introduction of these systems into production use.

INTRODUCTION

Resin-grouted cable systems have been in use for many years. Tadolini (1994) detailed the development of these systems with the use of resin capsules for enhanced coal mine roof support, but the length of the tendons described were short (6 m) in comparison to long tendon systems used in Australia (13 m). Long tendon cable support systems are used in both coal and metal mines. Resin capsules are only used with long tendons (6 m to 8 m in length) for point anchoring to enable pre-tensioning of the cable prior to full encapsulation of the cable with a cement grout. Also, resin capsules can only be used with single strand cable systems, due to mixing and anchorage issues with twin-strand systems. These issues make them unsuitable for the majority of hard rock cable systems, which are twin-strand in configuration. In addition to the mixing and quality of anchorage issues, resin capsule anchoring is often difficult where variation in borehole size is experienced. Initially, Portland cement cable bolts were "bottom up" grouted, using a Portland cement/water mixture. In more recent years, with advanced grout technology, grouts with low shrinkage and high strength properties have been introduced. Low slump grouts have also been developed to allow "top down" grouting of cables, particularly those cables that are point anchored and pre-tensioned using resin capsules. However, current cement grouting systems (grout and equipment) have some disadvantages:

1. Quality of grout has always been an issue; very rarely do operators mix grout to manufacturer's specification, often relying on the operators visual observations to determine whether the grout was of the correct mixture.
2. Low slump grouts require pumps that can pump a thick grout; choice of suitable pump is limited.
3. Pumping distance is limited with current grout pumps; operators often add more water to allow pumping long distance, which adversely impacts the quality and strength of the material.
4. Grout is mainly supplied in 20 kg bags; therefore, grout waste is excessive when a small number of cables are to be grouted (for example, a row of cables in a continuous miner heading).
5. Grout strength development is relatively slow in comparison to resin systems, thus making tensioning of cable system only possible after hours of cure rather than minutes.

Carbothix two component resin

Carbothix can best be described in the following statements:

[1] *General Manger - Operations Minova Australia. Wyong, NSW Australia, tom.meikle@:minovaint.com, M: +61(0) 407 289 209*
[2] *Chief Technical Officer Minova USA. Georgetown, KY USA*
[3] *Civil Business Manager Australia/Asia, robert.hawker@minovaint.com, M: +61 418 680 001*
[4] *Mining Engineer, Minova Australia. Nowra, NSW Australia*

- Two component Urea Silicate bonding resin used for long tendon cables and strata reinforcement bolts, e.g. Wiborex and Fibre Reinforced Polymer (FRP) bolts
- Used in Self- Drilling Rock Bolts (SDRB)
- Delivered via two component pump and hoses
- Mixed in volume ratio from 1(Part A):1(Part B) or 1(Part A):2(Part B) depending on the application needs and strength requirements
- Mixed at grouting site
- Reacts to form thick paste for "top down" grouting within seconds of mixing and sets within minutes to provide early load transfer between steel tendon and strata
- Early set time allows cables to be fully tensioned in less than 60 min
- No reaction with borehole water
- Low application pressures
- Cured resin is highly resistant to acidic and alkaline environments

Using the Minova long distance pumping system, Carbothix resin has been supplied a distance up to 2.5 km in Germany.

History of Carbothix use for long tendon grouting

Xstrata Nickel first trialed the use of Carbothix in 2006 at the Craig mine as part of its Sudbury Basin operations support plan (Pritchard and McClellan, 2011). The resin was initially used for grouting hollow core fibreglass rebar but was soon investigated for use with long tendon support systems. Cable bolts up to 10 m in length have routinely been fully grouted at the operation with great success, achieving full encapsulation by using Carbothix materials.

Other cable applications at the mine have enabled cycle times to be reduced by up to 24 hours compared to Portland cement cable systems. This is because the resin sets within one minute of cable grouting, and tensioning can occur less than ten minutes later. The initial resin used was a fast setting 1:1 formulation to accommodate the cool rock conditions. Some difficulty was experienced with this resin when using longer cables, which required the development and use of a slower setting version.

Carbothix has now been "fully" implemented at the Xstrata Nickel - Fraser and Nickel Rim mines, Goldcorp Musselwhite mine, Ontario, Canada, Resolution Copper, Arizona, Vale Birchtree and T1 mines in Thompson Manitoba, USA.

INTRODUCTION OF CARBOTHIX TO AUSTRALIAN HARD ROCK MINES

Initial trials at Cosmos Mine, WA, owned by Xstrata, where underground air and product temperatures were around 40 °C, were less than promising. Carbothix 1:2, at 24°C, has a set time of around 90 s; at 40°C this time is greatly reduced to around 25 s. Furthermore, the cables were installed in 62 mm holes. This would require approximately 16 L of product, but the pump output was set at 10 L/min.

Due to the temperature of the product, excessive pump pressures were seen - up to 20 MPa. Typically, this indicated that the carbothix was setting faster than anticipated and that the pump was attempting to push solidified Carbothix down the annulus of the borehole. Due to these conditions and some safety concerns, the trial was prematurely terminated.

Developing a slow set Carbothix

Following the less than successful first trial at Cosmos mine, Minova and Xstrata Nickel drew up a set of actions before commencing the next trial. Minova would formulate a slow set resin; Xstrata Nickel would review their current cable bolt drilling process and make the necessary operational changes in order to drill a 52 - 55 mm hole. With this in mind, Minova had to develop a resin that would work within a wider range of temperatures and had the same or similar mechanical characteristics as the current formulation.

Minova Australia's technical department commenced developing a slow set resin in March 2011, and finalised the formulation in May 2011. Laboratory testing showed that Carbothix slow set would provide slower gel time in a higher temperature environment but still enable sufficient strength development for tensioning the cable whether the resin temperature was 20°C or 40°C. Note the gel time is the time for resin to become free flowing whilst the set time is the time when final resin setting has occurred. Figure 1 shows the gel and set time comparisons at selected temperatures. The slower setting material took 10 s longer to set at 40°C and 25 s longer to set at 20°C. The slower setting materials were also able to sustain adequate shear strength properties, as shown in Figure 2.

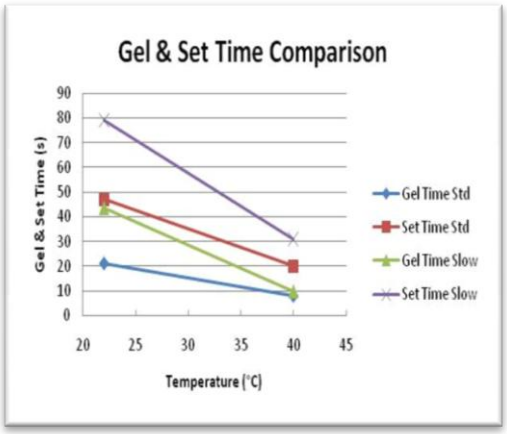

Figure 1 - Slow set resin gel and set time comparisons at selected temperatures

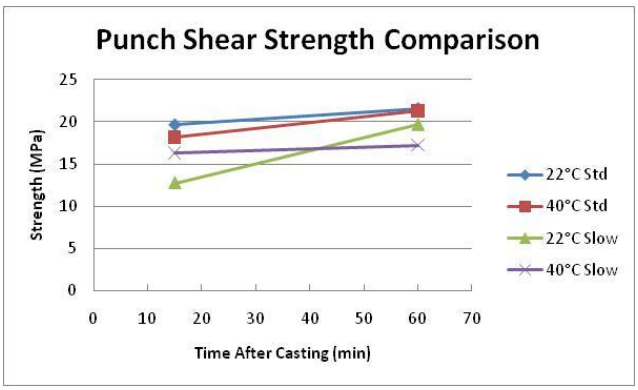

Figure 2 - Slow Set resin with shear strength properties at various temperatures

Surface trials of long tendon Carbothix grouting

Prior to carrying out underground trials, several surface trials were undertaken to:

- Ensure that the pumping system chosen could handle the product and deliver it at a consistent 1:2 ratio
- Ensure that the feed pipe system chosen could cope with system pressure
- Prove that 6 m and 8 m cables of various types could be fully encapsulated

Initial results in a laboratory environment, with Carbothix at 24 °C, were very encouraging; the pump delivered material at a consistent 1:2 ratio. Once the grout had set, cables were cut into sections to prove that full encapsulation had occurred. Figure 3 shows fully encapsulated twin-strand cables. Figure 4 shows a cross section of the Carbothix material fully encapsulating a megadowel strand bolt. The megadowel bolt is a 9 strand cable with a grout tube located in the center of the outside or sheath wires. The pump, shown in Figure 5a, is configured to deliver material at 1:2 ratios but that can be easily modified to pump 1:1 ratio depending on specific requirements. Smaller more mobile pumps are also available as shown Figure 5b.

Figure 3 - Cross-section of 6 m twin strand cables

Figure 4 - Cross-section of 8 m Megadowel

Figure 5a - Modified PHP pump

Figure 5b - Modified SK90 pump

IN HOUSE PRODUCT TESTING

Prior to use of Carbothix resin with long tendon supports, various tests were completed to compare the Carbothix's strength against both polyester capsule resin and also Portland cement cable grouts.

Initial punched shear testing, indicated the Carbothix resin was able to achieve one hour punched shear strengths of 26 MPa and 30 MPa after 24 hrs. This was compared to fast Lokset polyester resin, which achieved 24 MPa. Figure 6 shows punch shear results for various types of Lokset resins, Figure 7 shows Carbothix punch shear results.

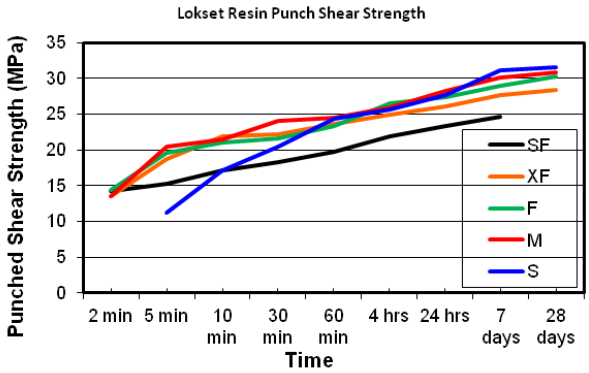

Figure 6 - punch shear results for various types of Lokset resins

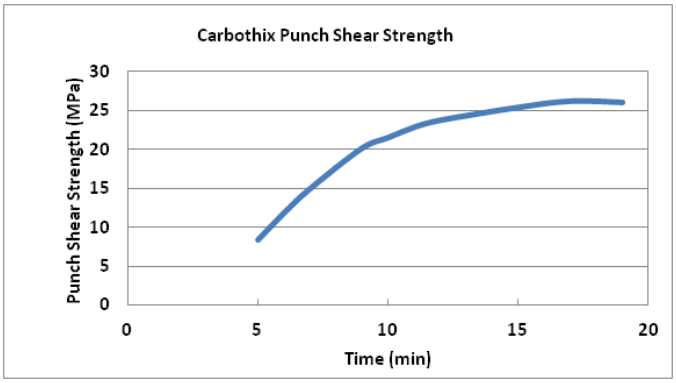

Figure 7 - Carbothix punch shear results

The Uniaxial compressive strength data for Carbothix was 70 MPa after 24 hours as shown in Figure 8, which is comparable to Portland cement cable grouts.

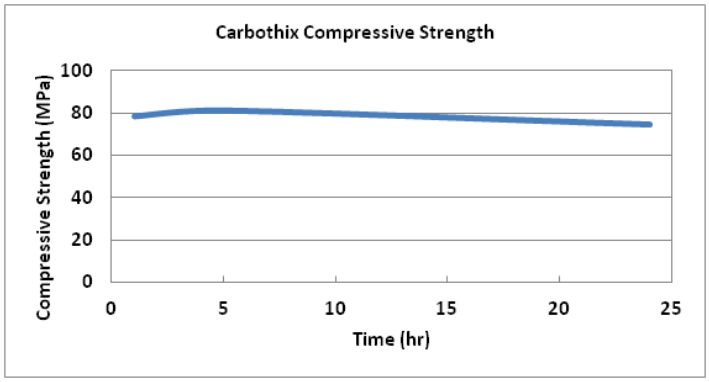

Figure 8 - Variation of the uniaxial compresive strength of Carbothex

To provide further confidence of the anchoring capability of Carbothix, further testing was done using various cable types and related borehole diameters. The laboratory testing method is shown in Figure 9. The cables were installed centrally then grouted in a steel pipe with 170 mm of anchorage medium and then "pulled" with a hydraulic jacking system. For a twin-strand bulbed cable, the Carbothix material reached anchorage strength of 7 kN in one hour. This compares with the identical style cable installed with General Portland (GP) cement that did not reach the 7 kN strength after 24 hours. This faster cure time makes it possible to post-tension the cables earlier, which can dramatically improve mining cycle times.

Figure 10 shows summary of results.

Figure 9 - The laboratory test set-up for pul testing of cables

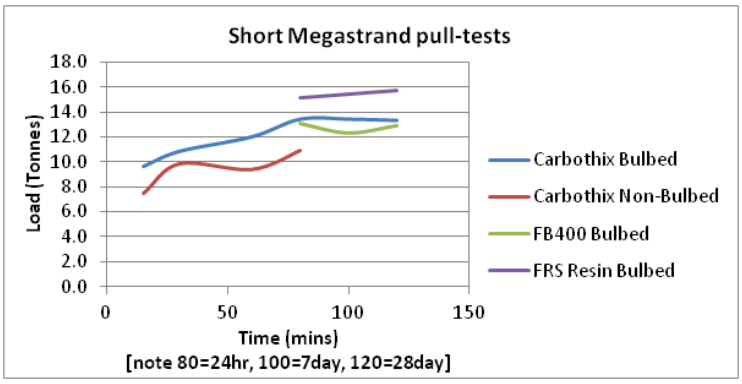

Figure 10 - Pull test results with pull duration

Further trials at Cosmos mine

Two further trials were carried out at Cosmos Mine using the new slow set formulation. In these trials, four different cable types were grouted in different ground conditions. The four types included single strand smooth cables, single strand bulbed cables, single strand de-bond cables, and twin-strand cables. The mine temperature varied between 31.8 °C and 36.1 °C due to various locations and ventilation conditions

in the mine. All of the cables were tensioned in excess of 20 t in less than 60 min. Subsequently, Xstrata Nickel Cosmos Mine has entered into a commercial arrangement with Minova Australia to supply Carbothix and accessories for long tendon grouting.

Four additional hard rock mines have commenced using Carbothix for cable grouting, and all of the mines are seeing substantial reductions in cycle times and outstanding support performance. Figure 11 shows a double strand cable installed and waiting for tensioning and plating.

Figure 11 - Double strand cable

INTRODUCTION OF CARBOTHIX TO AUSTRALIAN COAL MINES

The use of polymer materials that react *in situ* in underground coal mines is regulated under the Coal Mines Health and Safety Regulations 2006. These products are controlled using a license system, and the only systems exempt from these controls are traditional resin capsules.

Prior to the processing of the license application, the product must pass certain characterization tests, which include flash point, fire resistance, flame propagation, reaction temperature, oxygen indexing, and electrical resistance. Carbothix is the only pumpable resin approved for use with cable and bolting systems.

Minova Australia commenced the application process to the New South Wales (NSW) Department of Industry and Investment (DII) for Carbothix to be used in self-drilling rock bolts in 2010, and a limited "trial" license was granted that same year. The trial was limited to Tahmoor Mine, part of Xstrata Coal NSW Group. During these trials, air sampling was carried out by Coal Services Health to determine if Isocyanate was produced by the pumping process. Results showed that Isocyanate was not detected at any stage during the trial.

Following these trials, Minova Australia applied for an extended license to include the grouting of long tendon supports at any mine in NSW. This trial license was granted in November 2010.

Underground trials

The first underground trial was carried out at the Centennial Coal Mandalong mine. Ten 8-m-long cable trusses were installed to provide additional support in the LW12 tailgate, No 3 cut through area. All 20 cables were grouted with Carbothix standard set formulation due to the low underground temperature (18 degrees Celsius, and cables were trussed and tensioned after 30 min. Air analysis monitoring was carried out by Coal Services Health, and no MDI was detected.

Further underground trials were carried out at Centennial Coal Angus Place Mine, where several 8 m megadowels were grouted successfully using standard set resin. Again, air analysis was carried out by Coal Services Health, and zero Isocyanate MDI was detected.

Minova Australia has now applied to the NSW Department of Trade and Investmentfor a full license to allow full implementation of the system in coal mines in NSW.

CONCLUSIONS

There are several significant advantages of using Carbothix 1:2 resin for grouting long tendon cables with pumpable resin:

- Fast set allows early tensioning of cable bolts;
- Cables can be grouted immediately after tensioning;
- Ability to grout single cables, particularly in boggy or high shear ground;
- High early load transfer;
- Rapid resin set time; allows "in cycle" bolting;
- System can be adapted to be used with most grouted cables.

New developments of Carbothix grouting systems offer the advantage of safety, speed and reliability in a range of temperature conditions. The strengths are comparable to traditional cement-based anchorage systems while reducing mining cycle times. The recent acceptance of the material for coal mine applications is bringing forward several unique solutions for difficult ground conditions.

Use of Carbothix in the grouting of long high-capacity cables and truss systems has become routine at a number of operations leading to increase in development rates. Additionally, Carbothix is being used in self-drilling rock bolts) currently being tested in a full-scale program. The ultimate goal is to make the ground conditions safer for workers while improving operational efficiencies.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the effort of the Minova Australia support teams in the development of this innovative solution. Special thanks are extended to Michael Rockhoff, Minova, for assisting with initial underground trials in Western Australia and Rob Hawker's team for developing the new slow set, low viscosity Carbothix 1:2 resin for these applications. We would also like to recognize the mine site personnel at Xstrata Nickel Cosmos Mine, Centennial Coal Mandalong and Angus Place Mines for providing underground trial sites and operational support.

REFERENCES

Tadolini, S, 1994. Resin grouted cables for enhanced coal mine roof support. *Technology News*. U.S. Bureau of Mines, United States Department of the Interior. No. 433.

Pritchard, C J and McClellan, R S, 2011. Injectable resin - a highly adaptable ground support anchoring system. *Canadian Institute ofMining Metallurgy and Petroleum Conference and Exhibition*.