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Development, Trials and Testing of a Two Componet Rapid Set Cement Grouting System

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DEVELOPMENT, TRIALS AND TESTING OF A TWO COMPONENT RAPID SET CEMENT GROUTING SYSTEM

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ABSTRACT: In unfavorable strata conditions, it is often necessary to install additional long tendon support as part of a primary support cycle. Although these support systems provide the required additional stability to the roadway, installation does have a significant effect on the rates of development. To overcome the slow cure time of Portland cement type grouts, the use of two component resin systems such as Polyurethanes and Urea Silicates have become favored but concerns over creep properties has led to the development of a new two component grouting medium which displays the properties of traditional cable grouting materials with the rapid reaction times of pumpable resin systems. This paper describes product testing, product application - surface trials, underground trials and full-scale applications of the Tekthix system in a dynamic underground environment.

INTRODUCTION

Single component cement grouts have been used to anchor long tendon supports for many years. They range from basic high and low slump Portland cement-based slow setting grouts to fast setting single component grouts. However, current cement grouting systems (grout and equipment) have some disadvantages:

1. Low slump grouts require pumps that can pump a thick high viscosity grout, so choice of pump is limited.
2. Pumping distance is limited with current cable bolt grout pumps; operators often tend to add additional water to allow pumping long distance, which adversely impacts the quality and strength of the material.
3. Fast setting grouts tend to cause issues with pump and line blockages due to reduced working life of these single component materials.

The industry required a fast setting grout that could be pumped further than current single component grouts, whilst still having high values for UCS, Young's Modulus, Flexural and Adhesive strengths. Any change to current ground control systems, requires intensive testing to take place to ensure that the support system used has not been compromised by any change Tekthix has been developed to meet these requirements.

TEKTHIX TWO-COMPONENT CEMENT GROUT

Tekthix can best be described in the following terms:

- A two component cement grout
- Used for grouting of any long tendon support system
- Individual components mixed at water: powder (w:p) of 0.35:1
- Mixed Part A with Part B in a volume ratio of 1:1
- Capable of being pumped in excess of 200 m to point of application
- Mixed through static mixer at site of application
- Reacts quickly 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.

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LABORATORY TESTING

The following laboratory tests were carried out on the product:

- Uniaxial Compressive Strength
- Flexural Strength
- Tensile Strength
- Young's Modulus
- Creep Testing
- Adhesive Strength
- Viscosity of single components
- Double Embedment Pull Testing

TESTING REGIME

Mechanical properties

The Tekthix individual components were mixed at the corresponding water to powder ratio of 0.34-0.35: 1 at room temperature. Following this the two mixtures were mixed together at a 1:1 ratio by volume and cast into various cubes and cylinder moulds for testing. The samples were left to cure at room temperature for the corresponding period of time then tested using either 500kN compression machine also a Shimadzu 50 kN compression machine.

Uniaxial Compressive Strength (UCS)

The UCS of Tekthix ranged between 25 MPa at one hour and 75 MPa at 28 days. By comparison, currently used Portland based cement grouts have UCS values in the range of 30 MPa at 24 hours and 70 MPa after 28 days – Figure 1 and Figure 2.

Figure 1 shows Tekthix UCS at 0.34:1 and 0.35:1 Water/ Solids ratio. Figure 2 shows the comparison of UCS with two other single component grouts from 1 hour to 28 days.

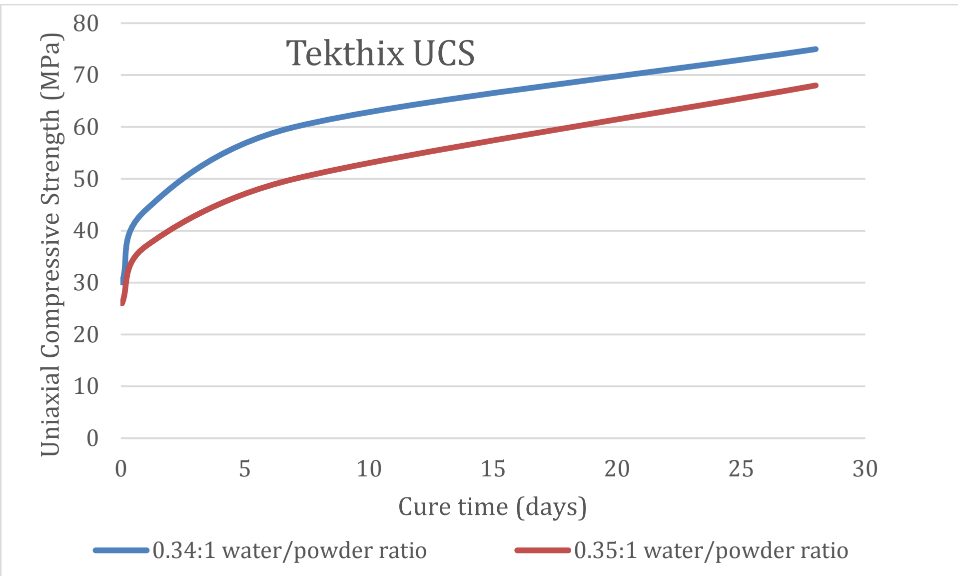


Figure 1: Tekthix UCS at 0.34:1 and 0.35:1 water /solids ratio

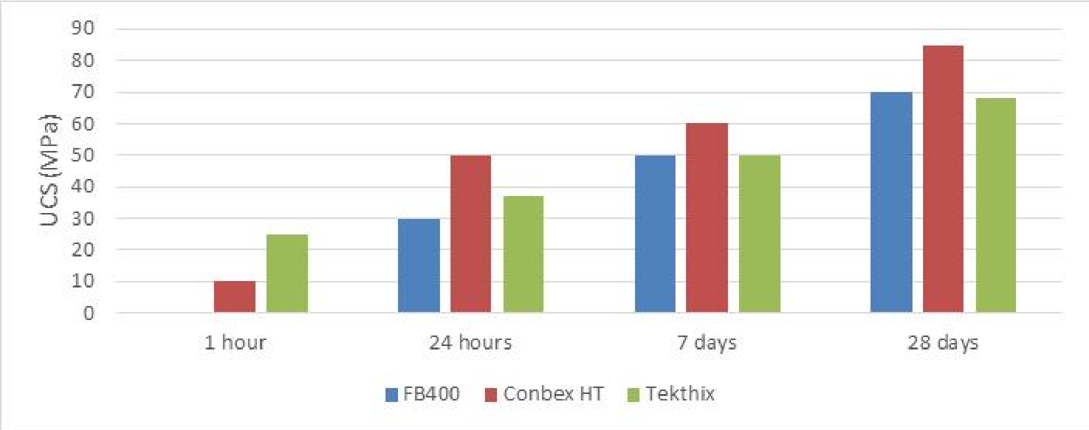


Figure 2: Comparison of UCS values of Tekthix with two other single component grouts from 1 hour to 28 days

Flexural Strength

Figure 3 shows Flexural strength growth at 1hr, 24hrs and 7 days, Figure 4 shows sample being tested in the Shimadzu 50 kN compression machine. The Flexural Strength of Tekthix ranged between 2 MPa at 1 hour and 8 MPa at 7 days.

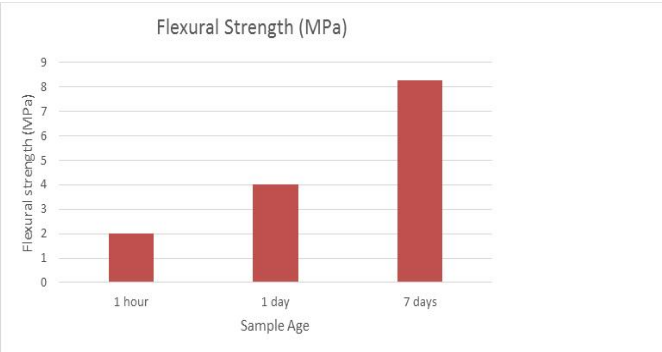


Figure 3: Flexural strength growth at 1hour, 24 hours and 7 days

Figure 4: Shimadzu Test Unit

Tensile Strength

The Tensile Strength of Tekthix ranged between 3.5 MPa at 1 hour and 5.5 MPa at 7 days. Figure 5 shows results for, 1 hour, 1 day and 7 days. Figures 6 and 7 show the testing process using the Shimadzu 50kN compression machine.

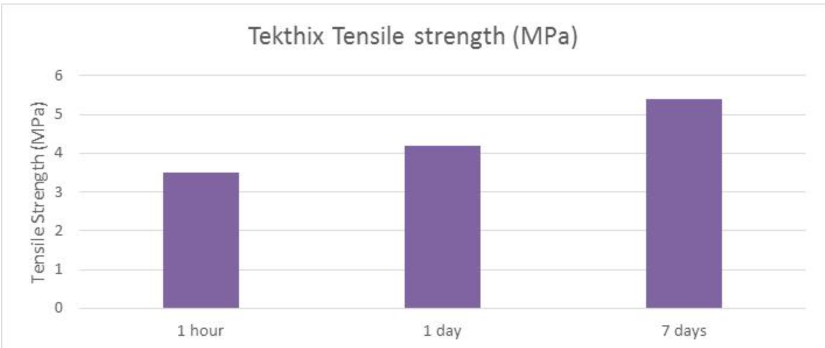


Figure 5: Tensile strength of Tekthix for 1 hour, 1 days and 7 days

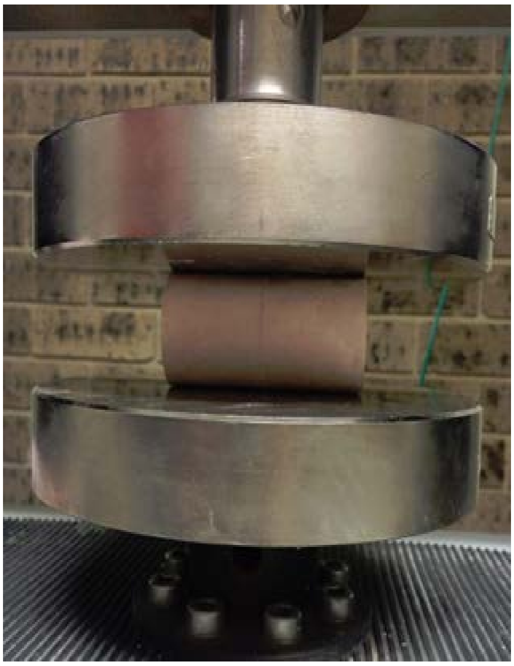


Figure 6: Axial tensile testing of sample

Figure 7: Post-test split sample

Young's Modulus

Figure 8 shows Young's Modulus after 1hr, 24hrs and 7 days. Young's Modulus values ranged from 3000 MPa after 1 hour to 4600 MPa after 7 days, by comparison, two component Urea Silicate grouts or Polyurethanes have Young's Modulus values below 1000 MPa.

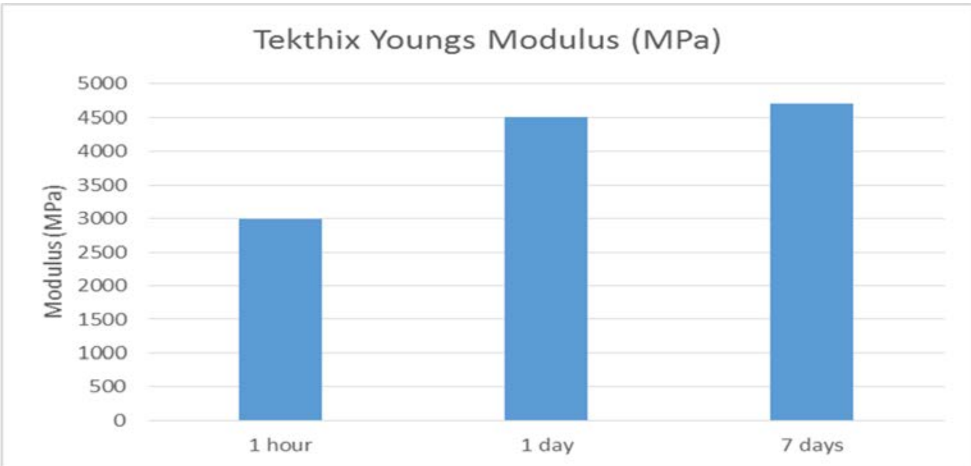
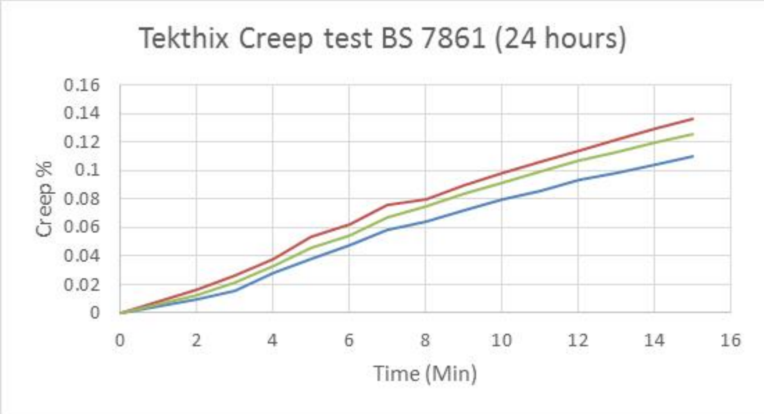


Figure 8: Young's Modulus of Elasticity of Tekthix grout at various curing times/ages

Creep (BS7861)

Samples of dimension 12.5 mm x 12.5 mm x 50 mm where subjected to constant load of 5 kN and the change in strain was measured between 30 seconds and 15 minutes. BS7861 calls for strain % of less than 0.12% to comply. Figure 9 shows percentage creep.



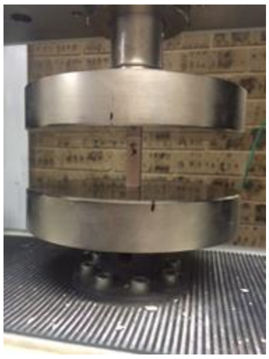


Figure 9: Rheological /Creep characteristic of Tekthix grout

Adhesive Strength

To evaluate bond strength of Tekthix in comparison to Geoflex Urea Silicate Resin, two sandstone blocks of dimensions 50 mm x 50 mm x 100 mm were bonded together with a bond width of 3 mm to 5 mm and left to cure for two hours. Figure 1 shows the average grout UCS after one hour of casting. The bonded blocks were then subjected to a flexural strength test and bond strength calculated.

Table 1: Average Stress N/mm^2

Time after casting	Tekthix	Urea Silicate
1 hour	3.17 N/mm^2	1.64 N/mm^2

Component Viscosity

As the viscosity of both components increases with time, it was important to understand individual pot life of both components. It was evident that if either component was left standing after initial mixing, that the viscosity would slowly increase to such an extent that it would have an effect on the pumpability of that component which could lead to pumping difficulties. The low viscosity of the individual Tekthix components enable pumping distances in excess of 200 m, by comparison to standard Portland cement grouts have a limitation of approximately 30 m with current pumps. Figure 10 shows rate of increase in Viscosity at 25^{o}C with product standing and mixing.

Double Embedment Pull Testing (DEPT)

This test was carried out using an Instron Hydraulic Universal Testing Machine. The objective of this test was to compare the load transfer performance of Tekthix and a common Industry used single component Portland cement grout, Stratabinder HS (SBHS) Tekthix testing was carried out after 4-5 hours, single component grout after 24 hours.

Grout details

The Tekthix grout used in the 320 mm steel tube sections was tested at 4 hours and gave a UCS of 35MPa. The Stratabinder HS grout used in the comparison 320 mm tube sections was mixed at 0.4:1 water to powder ratio, which when tested at 24 hrs gave a UCS of 20MPa.

Laboratory testing overview

The main aim of the laboratory testing was to determine the mechanical properties of Tekthix compared to current Portland cement single component grouts. In all aspects, Tekthix proved to have higher UCS, Adhesive Strength. Comparison of results achieved using the Double Embedment Pull Test (DEPT) test method has shown that Tekthix grout at 4-5 hours cure time) achieved double the peak loads over Stratabinder HS at 24 hours cure time when either the Secura HGC or Megabolt MW9 cable are used.

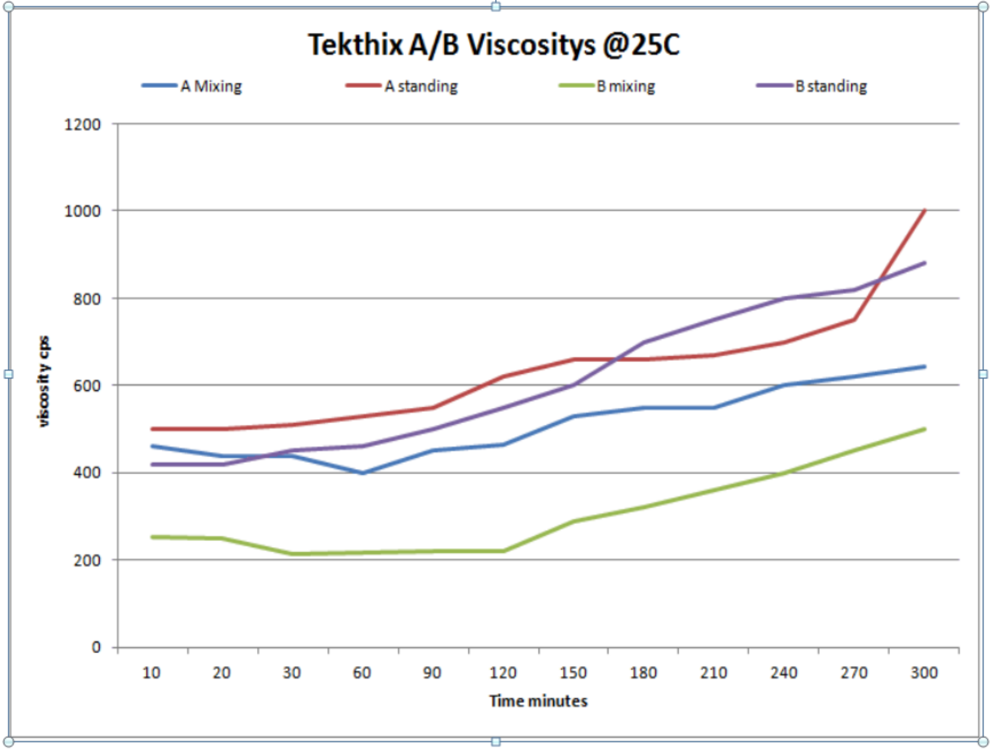
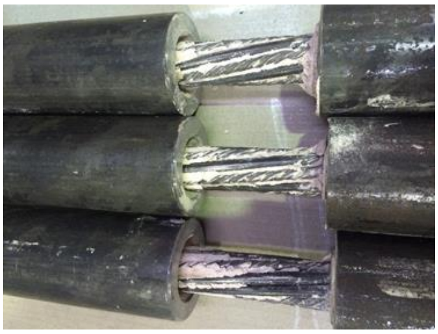


Figure 10: Tekthix A and B Viscosity changes at 25 °C, with respect to product standing and mixing

The results also showed that load stiffness between 50-150 KN is 40% higher on average for Tekthix (37 KN/mm) over Stratabinder HS (26 KN/mm) at the tested cure times. Total work energy to 100 mm displacement is also as expected over 40% higher on average for the six tests for Tekthix (25 kJ) over Stratabinder HS (10 kJ). These results clearly indicate the higher load support benefits for Tekthix at an early age over Portland cement type grouts such as Stratabinder HS even with 24 hours curing (cure) period.

Figure 11 shows Cable set up for DEPT, Figures 12 and 13 show cable after DEPT Testing and Figures 14 and 15 show results of DEPT on both the Secura and MW9 Cables using Tekthix.

Figure 11: Pull testing set up



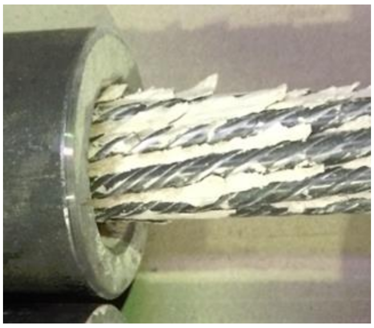


Figure 12: Post-test pulled out cable   **Figure 13: Close-up view of pulled out cable**

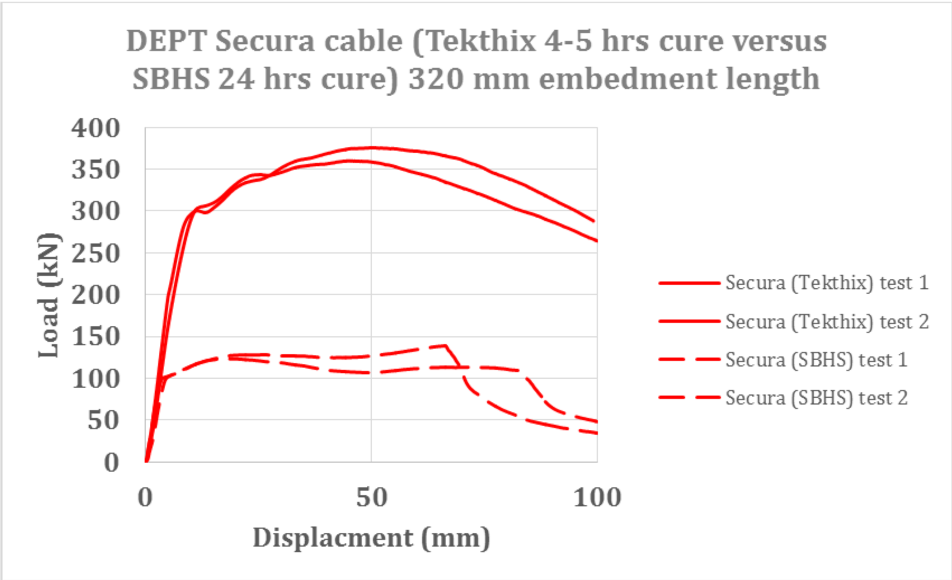


Figure 14: Load- displacement of Secura Cable bolt using different grouts.

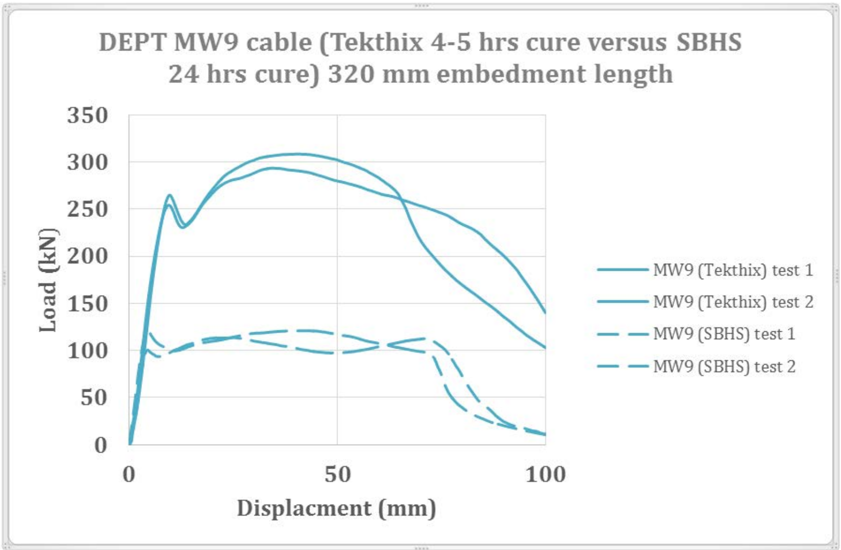


Figure 15: Load displacement of MW9 cable bolts with different grouts.

PRODUCT APPLICATION – SURFACE TRIALS

The following surface trials were carried out prior to any grouting trials.

Product recirculation through pump

The A and B components were mixed at 0.35:1 water to solids ratio and re-circulated through the pump for 4 hours to confirm:

- Pot life of individual components
- Separation of product
- Piston seal wear/damage
- Product build up inside pistons.

Re-circulation results

- Changes in viscosity caused by recirculating through the pump were no different from those found when mixing the product.
- There was no sign of the solid components separating from the water
- Delivery rate through the pistons remained unchanged and on target
- There was no visible sign of seal wear or damage
- There was no buildup of material in the piston or around the seals.

Maximum pumping distance and optimum hose diameter

150 m of DN20 hose was fitted to the outlets of each component cylinder. The pump was set at 60 cycles per minute (60 upward and 60 downward strokes), which delivered product at a rate of 12 liters/Min per side (24 liters per minute combined). Pressure gauges set in line showed zero pressure. A further test was carried out with 250 m of DN20 hose, which showed similar results.

Pump stall pressure

Pressure gauges and shut off valves were set in line to each cylinder. The pump commenced stroking at 60 cycles per minute and each valve slowly closed. When fully closed, output pressure. Figure was 120 bar.

Mixing nozzle configuration

The aim of these trials was to determine which mixing attachment both mixed the components correctly and achieved minimal backpressure. After several trials, a nozzle that consisted of DN20 fittings (Figure 16) and a 12 module x 16 mm static mixer (Figure 17) provided the best outcomes.

Figure 16: Grout mixing attachment DN20 fittings

Figure 17: Grout Static Mixer

Grouting trials

To simulate a cable inside a borehole, 6 m x 38 mm hollow cables were inserted into 40 mm conduit to confirm that the system could achieve full encapsulation Figure 18. 50 m of DN20 hoses were installed onto the pump. Once the grout was allowed to set, cables were cut into 2m sections to confirm full encapsulation Figure 19. This process was repeated several times with water temperature ranging from 24^{o}C to 30^{o}C.

Grouting outcomes

The system proved to be capable of pumping Tekthix through 50 m of DN20 hose and achieves full encapsulation each time. Figure 18 shows full encapsulation of 6 m cables. Figure 19 shows cable cross section.

Figure 18: Full encapsulation of 6m cables

Figure 19: Cable cross section

UNDERGROUND TRIALS

The first underground trial was carried out at a New South Wales Coal Mine. A series of hollow cables were successfully grouted without any issue. Grouting time ranged from 3 – 4 minutes. Grout was seen issuing from the telltale hole in the plate confirming full encapsulation had been achieved. Pump strokes were counted to confirm the volume of grout pumped into each cable was equal to or greater than the theoretical volume of annulus and grout tube inside the cable. Figure 20 shows grout lance attachment, Figure 21 shows grout tell tale.

Figure 20: Grout lance attachment

Figure 21: Grout Tell Tale

Having reviewed the results of the initial trail, and additional product testing information provided by Minova, the mine decided to fully implement Tekthix in the widening of the next longwall installation road. The first pass of the installation road at 5.5m wide is followed up by a 2nd pass of 2.5 m wide, to achieve a total width of approximately 7 m. The second pass consists of cutting to full width for approximately 20 linear meters. In order to provide additional stability to the wide span, a series of fully grouted, 6 m and 8 m long tendon cables are installed. Using standard single component grout, the grout is allowed to set for a minimum period of 24 hours before cutting of the 2nd pass recommences.

With the rapid set time of Tekthix, the wait time was reduced to less than 4 hours. A total of 350 cables were installed and grouted with Tekthix reducing the strip out time substantially.

CONCLUSIONS

The Mechanical properties of Tekthix two-component grout are equivalent to, or greater than current single component grouts. In addition, Tekthix also offers the additional advantage:

- Rapid strength gain allowing in cycle bolting and substantial reduction in cycle times,
- Higher Load Transfer performance than single component grouts,
- System can be adapted to be used with any support system that uses cement grouts,
- Pumping distance way in excess of current single component cement grouts.

To date, over 1000 cables have been grouted using Tekthix, and at date of publishing, three more large campaigns are planned in both New South Wales and in Queensland coalmines.

Further development in the pumping and mixing system is ongoing in order to reduce mixing time of grout and also to explore pumping this type of grout from a surface installation to underground location.

ACKNOWLEDGEMENTS

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