THE APPLICATION OF GRP AND THIN SPRAY LINER SUPPORT PRODUCTS IN A TYPICAL BLOCK CAVE MINING METHOD TO ENHANCE SAFETY AND PRODUCTIVITY

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Minova RSA

Abstract

A typical sub-level block cave mining extraction method employs an undercut level to establish a cave in hard rock and as such requires special support methods and products to be installed during the development phase.

The undercut level development in the block cave ore body is then sacrificial and support elements eventually will report to the crusher and perhaps conveyor belt systems for transportation to surface. The choice of support products installed in the undercut level development should take cognizance of the detrimental effect these could have on the mining system such as cutting of conveyor belts, obstructing crushers, safety aspects and productivity.

The author wishes to explore the probability and practicality of making use of new generation support products to make the operation safer as well as enhance productivity in the development phase and during the undercut operation.

This paper will investigate the use of Glass Reinforced Plastic (GRP) rockbolts and GRP mesh instead of conventional steel bolts and mesh along with resin capsule filled holes with the GRP bolts. Complementing this with Thin Spray Liner (TSL) application as another means of creating a safer operating environment as well as a productive support medium will also be addressed. These proposed items are envisaged to reduce production down time and improve the safety of our people. These items are all easy and light to handle, cut able and crusher friendly as it will break-up during these processes.

Introduction

Thin Sprayed Liners

Pressure to provide a workplace free from injuries and fatalities has added to the worldwide market pressure to improve profits and margins in the mining industry.

A rockfall study (Potvin et al 2001) conducted in 26 Australian underground metal mines has shown that over 90% of rockfall injuries involved in rocks smaller than 1 tonne. Furthermore, studies have shown that most injuries in underground mines have occurred within a few meter of the active face. This suggests that the current approaches in controlling the small pieces of exposed rocks near the active face where mineworkers are consistently
exposed can be improved. The approaches used range from using no surface support to the installation of mesh (steel & fibre) and in poor ground conditions the installation of shotcrete. While applying the current methodology near the face would likely reduce the risks of rockfall injuries, it could negatively impact the operations with regards to cost and mining cycle times.

TSL’s can address the above mentioned problem. The installation of surface support using remote and rapid spraying techniques has the potential to minimise interference with the mining cycle and reduce costs. TSLs can be applied essentially on or at the face to keep the small key blocks in place and reduce the potential of gravity induced fallouts of small pieces of rock.

The products discussed in this paper were all developed by Minova RSA, the intent being to compare the characteristics of each type of product against one another, rather than against those of competitive products. Minova RSA for the purpose of this investigation has chosen to evaluate their products against the following set of criteria:

- Characteristics of various TSLs
- Ease of application
- Product Quality Performance
- Spray ability and coverage
- Comparison to shotcrete
- Scale of Interference with the Mining Cycle

The first part of this paper will describe the characteristics of Capcem KT - TSL range.

The second part of the paper will describe the characteristics of the Glass Fibre Reinforced bolts and mesh.

1. Thin Spray Liner Characteristics

Minova RSA’s range of Capcem KT- TSL technical characteristics are as follows at 25 degrees Celsius:-

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>TEKFLEX</th>
<th>WHITE</th>
<th>GREY</th>
<th>FAST</th>
<th>FAST 2C</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMPRESSIVE (MPa)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 hours:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hours:</td>
<td>A flexible product</td>
<td>0</td>
<td>17.2</td>
<td>6.3</td>
<td>18.9</td>
</tr>
<tr>
<td>7 days:</td>
<td></td>
<td>31.1</td>
<td>21.5</td>
<td>20.6</td>
<td>20.8</td>
</tr>
<tr>
<td>28 days:</td>
<td></td>
<td>2.3</td>
<td>45.7</td>
<td>32.4</td>
<td>29.1</td>
</tr>
<tr>
<td></td>
<td>2 hours:</td>
<td>24 hours:</td>
<td>7 days:</td>
<td>28 days:</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>----------</td>
<td>-----------</td>
<td>--------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>TENSILE (MPa)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 hours:</td>
<td>0</td>
<td>0.21</td>
<td>2.1</td>
<td>5.15</td>
<td></td>
</tr>
<tr>
<td>24 hours:</td>
<td>0.21</td>
<td>1.4</td>
<td>1.6</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>7 days:</td>
<td>2.1</td>
<td>2.1</td>
<td>2.6</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>28 days:</td>
<td>5.15</td>
<td>3.1</td>
<td>3.1</td>
<td>3.9</td>
<td></td>
</tr>
<tr>
<td>SHEAR (MPa)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24 hours:</td>
<td>1.1</td>
<td>6.93</td>
<td>5.42</td>
<td>11.91</td>
<td></td>
</tr>
<tr>
<td>7 days:</td>
<td>3.0</td>
<td>13.93</td>
<td>9.04</td>
<td>13.56</td>
<td></td>
</tr>
<tr>
<td>28 days:</td>
<td>3.75</td>
<td>15.55</td>
<td>9.55</td>
<td>17.97</td>
<td></td>
</tr>
<tr>
<td>ADHESIVE (MPa)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 days:</td>
<td>3.0</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>56 days:</td>
<td>3.1</td>
<td>~ 0.2</td>
<td>~ 0.2</td>
<td>~ 0.3</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 1** Minova TSL characteristics summary

The Capcem KT range of TSLs provides a protective coating to rock, concrete or coal surfaces which are susceptible to deterioration on exposure to mine atmosphere, or as a TSL for support.

These products are all compressed air propelled onto the rock surface. Development of a full liquid TSL which does not require compressed air for propulsions onto the rock surface is in an advanced stage of development.

Critical requirements of TSL’s have been identified as follows:

- Adequate pot life when mixing i.e. more than 30 minutes
- Factory pre-mixed products for consistent performance of product
- Fast development of strength for rapid performance after two hours of application i.e. compressive, tensile and shear
- Excellent adhesion i.e. bonding to the substrate
- Visibility of the coating (white or light in colour)
Pneumatic application of equipment

Easily applied by one person

Visibility – White TSL Product
The support performance of TSLs is largely determined by the substrates onto which it is attached to and can greatly assist in maintaining the initial integrity of the rock mass under general loading conditions.

To ensure effective surface support design, it is important to fully understand the required reinforcing capabilities of the skin support. In friable ground conditions the first function of a TSL is to prevent the un-ravelling and loosening up of fragments, thus maintaining the rock mass integrity. If un-ravelling is not prevented, the support resistance within the rock mass will gradually decrease and the demand on the surface support will inversely increase.

Being in intimate contact with the rock surface, the coating action of TSLs bridges joints, effectively penetrates fractures and bond the rock mass together, thus restricting inter block movement.

The illustration below illustrates the interaction between various support components in a support system, represented as a reinforced beam loaded in an orthogonal direction.

![TSL block theory](image)

**Figure 2** TSL block theory

1.1 Classification of TSL characteristics could be as follows:

Laboratory interpretation of TSL technical characteristics could be as follows:-

(The classification below should be read in conjunction with the geotechnical requirements for the specific loading conditions that may be expected and may not all be equally important or applicable)

In selecting the most suitable TSL, cognisance must be taken of the specific requirements and intended application of the TSL. For example, in a static environment the requirement may be for a TSL with a high uni-axial compressive strength where tensile strength capabilities are less critical.
### Uni-axial compressive strength (UCS)

<table>
<thead>
<tr>
<th></th>
<th>10 Mpa</th>
<th>20 Mpa</th>
<th>&gt;30 MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak TSL</td>
<td>Average TSL</td>
<td>Strong TSL</td>
<td></td>
</tr>
</tbody>
</table>

### Tensile strength

<table>
<thead>
<tr>
<th></th>
<th>1 Mpa</th>
<th>3 Mpa</th>
<th>5 MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak TSL</td>
<td>Average TSL</td>
<td>Strong TSL</td>
<td></td>
</tr>
</tbody>
</table>

### Material Shear strength

<table>
<thead>
<tr>
<th></th>
<th>5 Mpa</th>
<th>10 Mpa</th>
<th>15 MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak TSL</td>
<td>Average TSL</td>
<td>Strong TSL</td>
<td></td>
</tr>
</tbody>
</table>

### Tensile adhesive strength

<table>
<thead>
<tr>
<th></th>
<th>1 Mpa</th>
<th>2 Mpa</th>
<th>4 MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak TSL</td>
<td>Average TSL</td>
<td>Strong TSL</td>
<td></td>
</tr>
</tbody>
</table>

### Shear bond strength

<table>
<thead>
<tr>
<th></th>
<th>1 Mpa</th>
<th>3 Mpa</th>
<th>5 MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weak TSL</td>
<td>Average TSL</td>
<td>Strong TSL</td>
<td></td>
</tr>
</tbody>
</table>

#### 1.2. Underground Application

Minova RSA TSLs are being extensively used at present in platinum and chrome mines with relatively limited application in other hard rock and diamond mines. The Capcem KT range is used in most applications with specialised Tekflex applications in vertical settler dams and raise bore holes for sealing against water leakage and in excavations requiring flexibility.

The success of applications stems from ease of mixing and spraying and ultimately the cleaning of equipment after use. All this leads to quick and cost effective spraying cycles and will determine the success of the TSL application. Good surface preparation is also essential for good bond.

Stress induced fracturing was observed in the rock mass surrounding the excavation and wedge type failure of rock occurred at the intersections of these and low angled joint sets, creating a very rough and uneven rock surface in the immediate hanging and sidewalls of the excavation. The condition of the rock mass around a tunnel is to a large degree controlled by the rock strength and the stresses it will be subjected to during its life cycle. In high stress conditions, sound design and excavation techniques are required to reduce early fracturing damage and to prepare the rock walls for the installation of support.
In these conditions, the installation of support at an early stage after exposure of the rock surface can significantly improve the prevailing ground conditions. It has become common practice in the deep level scenario to apply a thin layer of shotcrete as soon as possible after the blast to inhibit the adverse affect of stress fracturing and weathering, and to maintain safe working conditions till such time that secondary and more permanent support can be installed. However, it is often difficult to maintain the shotcrete within a reasonable distance from the advancing face, mainly due to logistical constraints and difficulty to fully integrate the shotcrete into the development cycle. TSLs have the potential to reduce accident levels and increase productivity, as the rapid spraying techniques involves minimized interference with the mining activity. In friable ground conditions the first function of a TSL is to inhibit the unraveling and loosening up of fragments, thus maintaining the rock mass integrity. In relatively large excavations, tunnels and a mechanized production environment, the application of TSL is very well suited to a robotic arm spray system for fast and efficient applications.

If unraveling is not prevented, the support resistance within the rock mass will gradually decrease and the demand on the surface support will inversely increase. Being in intimate contact with the rock surface, the coating action of TSLs bridges joints, effectively penetrate fractures and bond the rock mass together, thus restricting inter block movement. More permanent structural support such as thick shotcrete can be applied on top of the TSLs with good bonding.

1.3. **Capcem KT**

1.3.1 **Product description**

Capcem KT White and Grey have very similar properties and are supplied as a single component powder (pre-mixed in the factory) to which water is added. The main difference between Capcem KT White and Grey is the cement used and KT White cures to a brilliant white finish, whilst KT Grey cures to a light cement grey finish. Capcem KT Fast is a product developed by Minova RSA with the intention to provide early aerial support coverage to underground excavations offering strength after 2 hours. Capcem KT Fast 2C and Tekflex consist of two packed components i.e. a pre-mixed powder and a liquid polymer forming a kit.

The Capcem KT range forms a semi rigid support membrane that assists the rock to retain its initial integrity by reducing the adverse effects of scaling, spalling and weathering. It is supplied in 25 kg bags which produce on average 15 litres of product when mixed with 5.4 litre of water or polymer. It can theoretically cover 3.4m$^2$ if applied to a flat surface 5mm thick. However, due to the roughness factor of the underground rock, it is estimated that 2.5m$^2$ can be covered by one 25 kg bag or kit.
1.3.2 Application Methodology

Typical mixing arrangement

The contents of a number of 25 kg bags of Capcem KT White, Grey, or Fast is mixed together with clean water as per recipe, for approximately 4 minutes and then pumped (electric pump or compressed air driven pump), through a 25 mm hose to the spray nozzle some 15 m away from where it is sprayed onto the hanging and sidewalls either by hand held or robotic arm arrangement. The spray tempo is in the region of 500 to 800 litres per hour for effective application.

With continuous mixing of the TSL whilst spraying, a surface area of some 45 m² can be covered in 30 minutes. Thus, a total cycle time of some 35 minutes measured from into the tunnel to having moved out.
Minova RSA had done numerous panels tested with TSLs to determine the relative performance of the products. Tests were done with TSLs only and also with a combination of TSLs with a relatively thin webbing being sprayed over. The results are illustrated below:-
Figure 3 - Load application on Capcem KT Fast 2C used with Minova webbing

Figure 4 – Minova Webbing
One could conclude that TSLs offer a practical solution for limited ground support and if used in conjunction with appropriate webbing and followed in extreme cases by a layer of shotcrete, it offers a superb practical and mechanised solution to ground support in a sacrificial or permanent tunnel or excavation environment with the safest application method with very few people involved. All applications from the application of webbing to TSL to shotcrete can be done mechanised, remotely and fast.

### 1.3.3 Product Comparisons (Typical Cost Self applied with integrated crew)

<table>
<thead>
<tr>
<th>Description</th>
<th>Shotcrete (+25 mm)</th>
<th>KT 2C (+5 mm) 3m²</th>
<th>KT White (+5 mm) 3m²</th>
<th>KT Grey (+5 mm) 3m²</th>
<th>KT Fast (+5 mm) 3m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approximate ex factory product cost per m²</td>
<td>R 85</td>
<td>R 95</td>
<td>R 85</td>
<td>R 65</td>
<td>R 85</td>
</tr>
<tr>
<td>Approximate dedicated labour cost per m²</td>
<td>R 125</td>
<td>R 55</td>
<td>R 55</td>
<td>R 55</td>
<td>R 55</td>
</tr>
<tr>
<td><strong>Total cost per m²</strong></td>
<td><strong>R 210</strong></td>
<td><strong>R 150</strong></td>
<td><strong>R 140</strong></td>
<td><strong>R 120</strong></td>
<td><strong>R 140</strong></td>
</tr>
<tr>
<td>Rebound</td>
<td>Poor (lots of material)</td>
<td>Hardly any</td>
<td>Hardly any</td>
<td>Hardly any</td>
<td>Hardly any</td>
</tr>
<tr>
<td>Bags per m²</td>
<td>3.5</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>Kg per m²</td>
<td>88</td>
<td>8.35</td>
<td>8.35</td>
<td>8.35</td>
<td>8.35</td>
</tr>
<tr>
<td>Ease of Application</td>
<td>Cumbersome</td>
<td>Easy</td>
<td>Easy</td>
<td>Easy</td>
<td>Easy</td>
</tr>
<tr>
<td><strong>Time to cover 45 m² (conventional application)</strong></td>
<td>150 Minutes</td>
<td>55 Minutes</td>
<td>55 Minutes</td>
<td>55 Minutes</td>
<td>55 Minutes</td>
</tr>
<tr>
<td>Equipment</td>
<td>Large</td>
<td>Small</td>
<td>Small</td>
<td>Small</td>
<td>Small</td>
</tr>
<tr>
<td>Interference with development cycle</td>
<td>High</td>
<td>Minimal</td>
<td>Minimal</td>
<td>Minimal</td>
<td>Minimal</td>
</tr>
</tbody>
</table>

*Figure 5 – Product Comparisons – Cost, Application, Time*
*Product cost may vary slightly per m² from operation to operation due to surface areas. Labour cost for application could be very different from the numbers quoted above especially if the application crew is not part of the development crew.

**With continuous mixing arrangement of the TSL products, the application time can be limited to 30 minutes per application cycle followed by washing out the equipment before the next use. Minova RSA will ensure appropriate pump and mixing arrangements to allow for continuous mixing and spraying with the development cycle and equipment selection for development.

1.3.4 Spray Equipment

The ease of application of TSLs will ensure minimal interference with the development cycle and improve safety and productivity. The equipment required for TSLs are small when compared to conventional shotcrete equipment and can readily be moved between sites. There are various types of TSL pumping and mixing equipment available, however the use of equipment with independent mixing and pumping arrangements is recommended to reduce application cycle times.

1.3.5 Logistics

In the case of 25mm shotcrete, approximately 158 x 25 kg bags are required to cover an area of 45 m², which equates to ±4 tonnes of material. In the case of 5 mm TSLs such as Capcem KT, 23 x 25kg bags or ½ a tonne of material is required to cover 45 m².

The use of TSLs can significantly reduce the demand on the already burdened logistical systems of the mine whilst maintaining safer mining conditions right at the advancing face. A typical conventional development cycle might consist of the following:

- Cleaning operations
- Making safe
- Installation of temporary support (jacks and netting)
- Marking off support holes
- Drilling and installation of support
- Marking off of the round
- Drilling the round
- Charging up and blasting
- Removing temporary support
- Re-entry

Depending on the requirements, the application of surface support liners should ideally be integrated into the overall production cycle where it is most practical and causes the least interference with the development cycle. If it is required to apply the surface liner from the last line of permanent support up to the face, then ideally this activity should take place immediately after the installation of temporary support or even permanent support if a resin bolt installation is chosen.
In a bad ground undercut development end the support regime might call for the following support:-

- A bolting pattern
- Shotcrete at 25 mm thickness
- Steel mesh and or lace installation
- Shotcrete at 50 mm thickness

With the new generation support available the following could be proposed:-

- GRP or synthetic netting installation with netting installing unit mounted to face jumbo
- 5 mm TSL on washed and made safe development rock surface with robotic arm applicator
- A GRP and resin capsule bolting pattern with a mechanised bolter, this could be adequate to safely allow critical and in-line activities to continue at the face and then follow up with
- 50 mm Shotcrete approximately 20 m behind the advancing face

What we attempt to demonstrate is that a combination of TSLs, appropriate netting, GRP bolts and shotcrete will offer the same support resistance but with less material, faster development cycles, safer development methods and support products that can be broken up and destroyed when undercut level gets blasted away and product goes through the crushers.

Allowance must be made in the production cycle for at least half an hour for the application of the TSL assuming the product and equipment is on site. This excludes the time taken to set up the equipment and the cleaning afterwards. Furthermore, it could be advantageous to spray a thin layer of TSL over the previously sprayed surface of the previous blast to increase the TSL thickness to say 8mm and produce a good and consistent cover and protection.

1.3.6 Conclusion

Rock related accidents are the major cause of injuries and fatalities in underground mines and most of these accidents occur near the active faces where workers spend most of their time. One of the major causes of instability is the lack of support and/or coverage between support units. Support tendons alone do not provide sufficient rock reinforcement in friable ground conditions and hence the potential of gravity induced fallout of small pieces of rock.

TSLs have the potential to benefit the mine by offering improved productivity, profitability and safety. From a manufacturing perspective it is very unlikely that all the characteristics that TSL could have can be included in one “super” product. For this reason the proper selection and application of the correct TSL is very important to be able to significantly improve ground conditions and reduce related injuries.

INTRODUCTION TO GLASS FIBRE REINFORCED PLASTIC BOLTS AND MESH

In 1985 Weidmann AG, a company in Switzerland started with the development and manufacture of a range of GRP rockbolts which were then used for the first time in tunneling
projects in Switzerland. The GRP bolts were installed as permanent support together with steel mesh and shotcrete in numerous tunnels constructed in the single shell method.

GRP bolt technology has since found widespread application in the mining and civil engineering industries. Compared to steel, glass fibre reinforced plastics (GRP) have advantages that can be traced to the properties of the composite material. It offers high resistance to corrosion, high tensile strength, light weight and is easily cut through.

The application of glass fibre reinforced plastics offers various possibilities. In cooperation with Rockbolt Systems (Switzerland), the Minova group offers a range of GRP bolts suitable for various rock support applications.

Minova RSA has also developed a range of TSLs suitable for use as underground containment support or for weathering protection.

**GRP Description**

GRP bolts simply consist of a composite of resin and fibre that is manufactured through the pultrusion manufacturing process which were developed in the early seventies. The raw materials (fiber and resin) are pulled through a die, which gives the rods its shape and dimension. The rods consist of approximately 75% glass fiber and 25% resin. The fiber threads are continuous without damage or cutting of fibres during the manufacturing process.

![Figure 6 Illustrates a typical pultrusion process used in the manufacture of GRP bolts](image)

**GRP Properties**

Due to the high tensile strength and relative high modules of GRP, the bolt has a high and immediate load bearing capacity if applied with fast setting resin capsules. The high flexibility is well suited for application without couplings in confined locations and the low weight facilitates ease of handling. The high resistance to corrosion of GRP bolts makes it ideal to be used in highly corrosive environments.

**GRP bolts have several advantages if compared to steel bolts:**

- **Corrosion Resistant** – durable material and as part of the final lining supports a structure during its whole life span
- **Cutability** – avoids damage to cutter heads and does not delay excavation
- **Continuous Thread** – threaded over the whole length facilitates coupling
- **High Tensile Strength** – approximately double the load of a steel bar with the same diameter (Refer to fig 6, 7 and 7.1)
- **Flexibility** – GRP bolts can bend and therefore be used in confined spaces without the use of coupling elements
- **Low weight** – A GRP bolt weight is only a quarter of the weight of a steel bolt of the same dimension

![Figure 6](image)

**Figure 6**  
Comparison of material characteristics of GRP bolts vs Steel Bolts

![Figure 7](image)

**Figure 7**  
Comparison of GRP bolts vs various Steel Bolts  
Tests carried out at the Technical University of LULEA, Sweden
### Table 1: Material Characteristics for Weidmann GRP Bolts

<table>
<thead>
<tr>
<th></th>
<th>GRP</th>
<th>Steel</th>
<th>Aluminium</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specific weight (kg/dm³)</strong></td>
<td>1.9</td>
<td>7.8</td>
<td>2.7</td>
</tr>
<tr>
<td><strong>Tensile strength (N/mm²)</strong></td>
<td>1'000</td>
<td>600</td>
<td>350</td>
</tr>
<tr>
<td><strong>E-Modul (N/mm²)</strong></td>
<td>44‘000</td>
<td>207‘000</td>
<td>69‘000</td>
</tr>
<tr>
<td><strong>Ultimate strain (%)</strong></td>
<td>2.5 - 3.5</td>
<td>&gt; 10</td>
<td>&gt; 10</td>
</tr>
</tbody>
</table>

**Figure 7.1 Comparison material characteristics for Weidmann GRP bolts**

### Types of GRP Bolts

GRP bolts are well suited to be used as primary or secondary support as a standalone support unit or as an integral part of support systems. There are four different types of GRP bolts available namely, the all thread bolt K60 and J64, the self drilling tubular rod and the cable bolt.

#### K60 and J64 Bolt

The all thread K60 bolt can easily be installed using polyester resin capsules which lends its self very well towards mechanization or it can be grouted into place by the use of cement capsules or pumpable grout.

The J64 injection bolt (tube) was developed to facilitate the injection of cementitious grout, epoxy or silicate resin for ground consolidation or water sealing applications.

**Figure 8** Typical example of a K60 and J64 injection bolt
Self Drilling Bolt

The self drilling bolt was developed for use in weak rock or soil and can be coupled to lengths up to 20m, depending on rock or soil conditions. The bolts are suitable for use with a rotary drilling machine and can effectively penetrate rock with a hardness of approximately 60 MPa.

The bolts are set in place with cementitious grout or chemical grout and are most suitable for piling ahead of an advancing face developed in poor ground conditions.

Figure 9 Typical example of a self drilling bolt

GRP Mesh

FiReP® FRP POWERMESH was developed to comply with standard grid applications while providing the added benefits of durability and cut ability. High load capacity at each joint, compared to that of welded mesh, is unique and makes the design of Fibre Reinforced Polymer (FRP) grid reinforced RC structures a viable option for engineers and mining support structures.

Example:

Unit Standard 100 x 100 x 6 mm, Rod Diameter 6 mm
Breaking load of 6 mm rod >28.3 kN, Ultimate strength of 6 mm rod >1,000 N/mm²
Tensile E-Modulus 60,000 N/mm² and load of knot >3 kN and >5 kN
Overall dimensions 2,000 x 800 mm

Other Options:
- Available rod size 3 mm - 12 mm
- Other mesh sizes available on request
- Polyester / Epoxy / Vinyl ester resin
- Non flammable
- Anti-static coating
Corrosion Resistant

FiReP® FRP rockbolt systems are corrosion resistant and therefore the only currently available rockbolt system which can be regarded as permanent, even under difficult conditions with aggressive water and rock deformations. Corrosion is the most pressing material problem worldwide. With capital, downtime and material costs rising, corrosion prevention is high on many industries’ list of priorities. Every minute, several tons of steel are lost to corrosion. The cost of corrosion protection is enormous. Even with protection the corrosion problem is only delayed but not solved. Correctly applied FiReP® FRP rockbolt systems support the construction over its entire life.

Because of its anti-corrosion concept, the FiReP® FRP rockbolt technology is used increasingly for soil reinforcement and ground anchoring.

Single-Lining Support Systems

Because of the durability of the materials, FiReP® FRP rockbolt systems can be utilised not only as a temporary support, as with regular steel rockbolts, but also integrated into the calculation for the final load-bearing structure. In-situ concrete shells can therefore be reduced or even eliminated.

This so-called SINGLE-LINING tunnel construction method is widely used in Europe in military and civil caverns. The final support consists solely of rockbolts and reinforced shotcrete. With the achieved improvements of those materials, single lining tunnels will further increase in importance.

The cost reductions, especially in the large scale Alpine cross tunnels are enormous. The construction costs of a railway tunnel for low speed or a highway tunnel with moderate traffic can be reduced by up to 50%.

Figure 10  Typical example of a GRP Power Mesh
Applications of GRP

GRP bolt technology is especially well suited for use as temporary support units where cutter heads are used for excavation in hard or soft ground conditions. The cut ability of GRP allows for the cutters to cut through the bolt without causing damage to the cutting heads and costly delays and can easily be broken in a rock crusher reducing significantly damage to equipment.

GRP bolts are typically used at collieries during stooping operations, the collar and holing positions for raise boring machines or at the collar and holing position for tunnel boring machines and in aggressive corrosive environments.

Figure 12  Typical application of GRP bolts where cutter heads are used
GRP bolts can be used as a standalone support or in combination with various types of support mediums. In poor or friable ground conditions, GRP can be used in combination with webbing, netting, mesh, shotcrete or TSLs.

![Figure 13 Typical example of GRP bolts used in combination with wire mesh](image)

GRP bolts can also be used as self-drilling bolts in the appropriate applications. Resin injection is generally used to inject consolidation resin through the bolt to consolidate the very weak or friable rock.

![Figure 14 Typical applications of self-drilling bolts](image)
The very nature of the Block Cave Mining Method makes it ideal for exploring the benefits that could be derived from the use of GRP technology. The undercut development is sacrificial and the installed support will be destroyed once the undercut blasting and ore production commences.

The installed support will eventually report to the draw points where it could cause obstruction or worse end up on the conveyor belt systems with the potential of cutting the belts or cause obstructions in the crusher. The inherent properties of GRP can overcome the shortcomings of conventional steel type support and enhance safety and productivity.

In areas where poor or friable ground conditions are encountered, it is often necessary to consider the use of containment support in addition to tendon support. Common practice is to install wire-mesh and lacing or shotcrete or a combination of wire-mesh and shotcrete. Although these types of support are generally very effective in stabilizing very weak ground conditions, it is time consuming and costly, not to mention the logistical problems these may create.

Several TSLs suitable for various mining environments and geotechnical conditions are available and could be well suited as additional support or consolidation medium in the undercut level development in a block cave where this may be required. It offers a cost effective support solution as alternative or supplementary support to shotcrete in areas where the building of a structure is not a requirement.

The main advantages of TSLs if compared to shotcrete is the ease of application, speed of application, early strength, much reduced transportation of material, less labour intensive and cost effective. Thin Spayed Liners can be used as a temporary or permanent support medium depending on the requirements and prevailing geotechnical conditions.

As a temporary support medium it can be incorporated into the daily production cycle to maintain safe mining conditions at the face. This allows permanent support to be installed at a later stage without causing unnecessary production delays.

**Typical Undercut Development Support Strategy and Alternate Considerations**

The support strategy selected for a block cave undercut level is generally site specific and to a large extend depends on the undercut level design and local conditions. Drift support and reinforcement typically consists of polyester resin capsule anchored bolts.

Resin bolting offers immediate active and permanent support and the support regime is enhanced by the addition of an appropriate TSL applied directly at the development face after the blast and even further enhanced by the installation of the cutable GRP Power mesh or synthetic webbing along with TSLs.

Mesh can be installed mechanically by means of a mesh installer unit mounted to the face jumbo.
GRP bolts can be installed with a dedicated bolter unit making use of a carrousel bolting unit. The use of containment support such as shotcrete or mesh is considered only if conditions warrant its use.

GRP bolts is well suited to be used in the mechanized environment and hence can be used as an alternative to conventional steel bolts without compromising productivity or safety. It can also be used in combination with TSLs, shotcrete and mesh. GRP bolts are approximately 20% more expensive than resin anchored steel bolts of the same diameter. However, in some mining applications the benefits that are being derived from GRP far outweighs the additional cost.

Shotcrete and/or wire-mesh are commonly used to support undercut drifts where the containment of rock support may be required to ensure that excavations remain open and safe for their designed life. However, shotcrete or wire-mesh does not readily fit in with the development cycle and often result in reduced development efficiencies or support backlog.

Should the mining conditions permit, TSLs may be considered as a cost effective alternative or addition to shotcrete and other types of containment support. The main advantage of TSLs is that it can easily be integrated into the mining cycle providing support concurrent with the face.

A combination of GRP mesh or synthetic webbing covered by a layer of appropriate TSLs along with GRP bolt installations and followed by structural thickness of shotcrete makes much sense in a sacrificial development environment.

**Conclusion**

With technological advancement of support products and methodologies today, we are able to work safer, smarter and more productive with appropriate support requirements for our excavations.

The combination of a fully mechanized system of support commencing with the making safe of a working development end with a scaler and high pressure water jetting of the rock surface to eliminate smaller rock pieces from falling uncontrolled, followed by the mechanized installation of a webbing if required and this being covered with an appropriate thick layer of the correct TSL, allows in-line development activities to take place at higher tempos and perhaps safer than we generally do today.

The application of a then thinner layer of shotcrete on top of the TSL and webbing and bolts due to the already installed support completes a well supported development end with good quality support installed safely.

The authors believe that there is much merit in further investigating the economical application and implementation of appropriate new technology in mining and tunneling operations.
References


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