INVESTIGATION OF THE CHARACTERISTICS OF THIN SPRAYED LINERS (TSL) AND THEIR USE AS AN ADDITIONAL SUPPORT MEDIUM IN BLOCK CAVE MINING

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ABSTRACT

Block Cave mining is one method used to extract ore from underground diamond mines as well as other massive orebodies such as copper. This necessitates the excavation of many kilometers of tunnel within the ore body. The integrity of these excavations needs to be maintained over a number of years. Most Kimberlites and weak orebodies are extremely susceptible to degradation when exposed to moisture and the atmosphere. It is therefore essential that some form of weathering protection is applied as soon as possible after exposure.

Conventional methods of weathering protection such as shotcrete do not easily fit in with the production schedule, hence the need for a more efficient system that could be applied immediately after exposure and serve as a temporary support or even as a permanent support medium. The main advantages of thin sprayed liners (TSL) compared to shotcrete are the ease of application, speed of application, early strength, much reduced transportation of material, less labour intensive and cost effectiveness.

Several Thin Sprayed Liners suitable for various mining environments and geotechnical conditions are available and could be well suited as additional support the undercut level development in a block cave where this may be required. TSL offer a cost effective support solution as an alternative to shotcrete in areas where the building of a support structure is not a requirement.

INTRODUCTION

The term TSL (Thin Sprayed Liner) came into prominence during the late 1990's with the development of products which initially were designed to provide area support between roof bolts or packs, or to replace steel mesh. Prior to this, similar products had been used specifically on diamond mines in attempts to preserve the integrity of Kimberlite.

The composition of these early sealants varied from gypsum based plasters through polymer modified cement mortars to latex and similar chemical coatings. Many of these products had some beneficial effect, but in nearly all cases the application was slow and laborious, and were generally carried out far behind the developing face, where critical deterioration of the Kimberlites and other weak rock, had already taken place.

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

The conventional way of overcoming this problem is by the installation of wire mesh or the application of shotcrete. However, these support components have disadvantages; application of mesh is expensive and time consuming, while shotcrete results in logistical problems because of the relatively large volumes of material involved.

The alternative TSL surface support system has the potential to reduce accident levels and increase productivity, as nowadays the rapid spraying techniques involved minimise interference with mining activity. Thin Sprayed Liners 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.

As stated many times before, the design methods, application and requirements of TSL's is an emerging technology, with confused understanding of properties and attributes with each supplier and institution. The suppliers and institutions have their own standards, testing methods and comparisons to meet their own requirements. The products discussed in this paper were all developed by Minova RSA, and the intent is 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 criteria:

- Characteristics of various TSLs
- Ease of application
- Product Quality Performance
- Sprayability and Coverage
- Comparison to Shotcrete
- Scale of Interference with the Mining Cycle

The first part of this paper will describe some typical characteristics of Minova TSL and a case study. The second part of this paper will highlight the development of purpose-made products as well as specialized application methods for current and new products.

1. THIN SPRAYED LINER CHARACTERISTICS

Technical characteristics Minova RSA's range of Thin Sprayed Liners:-

Description	**Raplok** (+-5 mm)	**Tekflex** (±3 mm)	**KT White** (±5 mm)	**KT Grey** (±5 mm)	**KT Fast** (±5 mm)
Tensile Adhesive Strength (MPa)	0.5	3.0	0.34	0.53	0.5
UCS (MPa)	29	2.3	55	32	32
Tensile Strength (MPa)	3.38	5.15	3.69	3.09	3.99
Material Shear Strength (MPa)	8.97	3.75	14.0	9.86	9.8
Shear Bond Strength (MPa)	1.26	1.31	1.8	2.8	2.77
Colour	White	White	White	Light Grey	Light Grey

Fig 1: Minova TSL characteristics summary

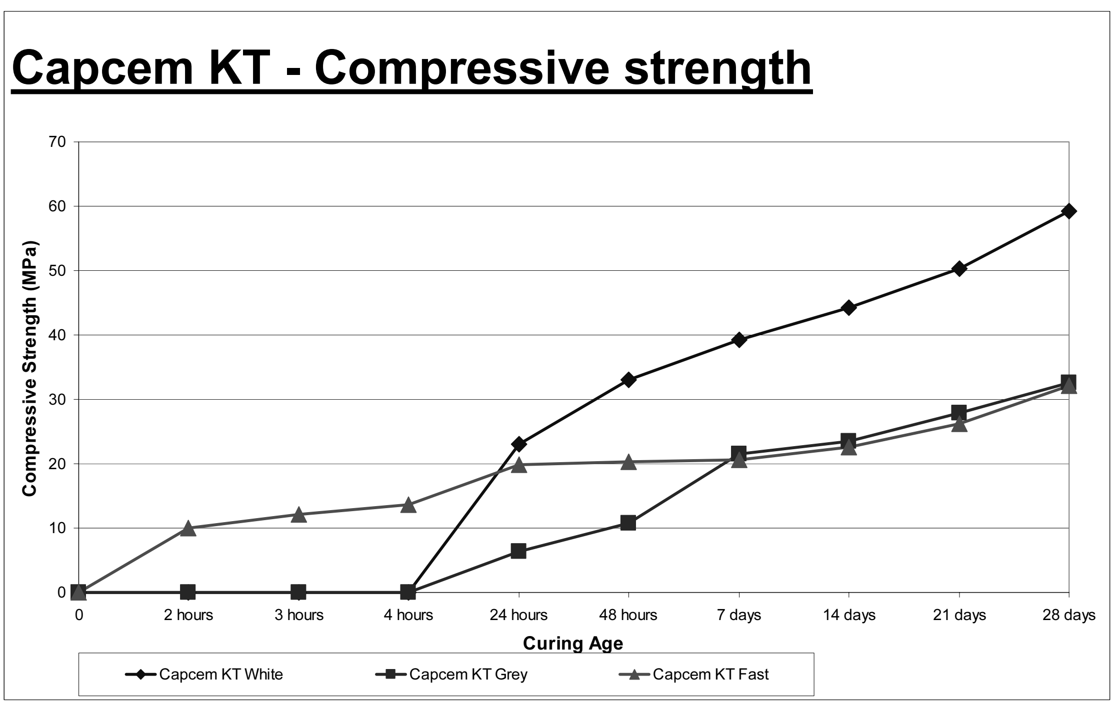

Fig 2: TSL Capcem KT range compressive strengths

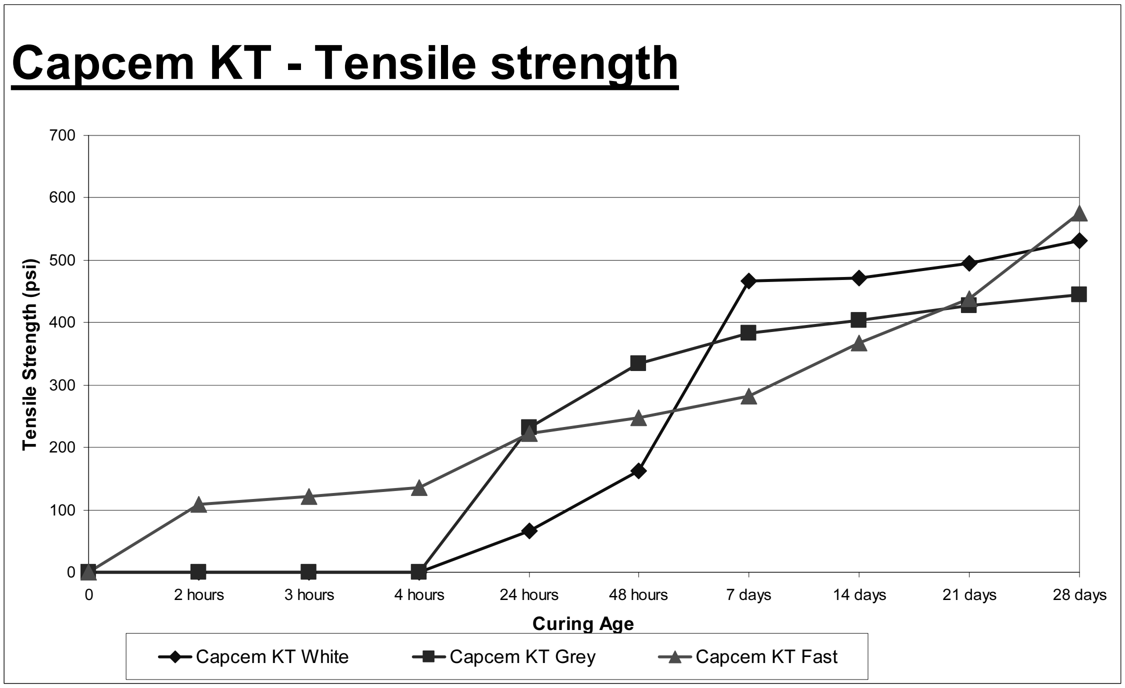

Fig 3: TSL Capcem KT range tensile strengths

The support performance of Thin Sprayed Liners is largely determined by the substrates onto which they are attached 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 thin sprayed liner is to prevent the unravelling and loosening of fragments, thus maintaining the rock mass integrity. If unravelling 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 thin sprayed liners bridges joints, effectively penetrates fractures and bonds 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.

1.1 CLASSIFICATION OF TSL CHARACTERISTICS BASED ON RESULTS OF LABORATORY TESTS:

A posible classification of TSL technical characteristics could be as follows:
(The clasification 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).

Uni-axial compressive strength (UCS)

10 MPa	20 MPa	>30 MPa
Weak TSL	Average TSL	Strong TSL

Tensile strength

1 MPa	3 MPa	5 MPa
Weak TSL	Average TSL	Strong TSL

Material Shear strength

5 MPa	10 MPa	15 MPa
Weak TSL	Average TSL	Strong TSL

Tensile adhesive strength

1 MPa	2 MPa	4 MPa
Weak TSL	Average TSL	Strong TSL

Shear bond strength

1 MPa	3 MPa	5 MPa
Weak TSL	Average TSL	Strong TSL

In selecting the most suitable TSL, cognisance must be taken of the specific requirements and application the TSL is intended for. For example, in a static environment the requirement may be for a TSL with a high uniaxial compressive strength where tensile strength capabilities are less critical.

1.2. UNDERGROUND APPLICATION

Minova 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 limited rock support.

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.

1.3 CASE STUDY – TSL TRIALS ON A DEEP GOLD MINE

Underground Rock Conditions
Recently additional trials were done at a deep gold mine on a main intake haulage. These haulages are being developed in an easterly direction and are situated in the Witwatersrand footwall quartzite, 2733m below the surface. The haulages are developed 4m wide, 5m high and the planned advance is 90m per month per end respectively. It is planned to keep the tertiary permanent support within 150m from the advancing face.

Stress induced fracturing was observed in the rock mass surrounding the excavation and wedge type failure of rock occurred at the intersections of these fractures 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 effect 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. Thin Sprayed Liners 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 thin sprayed liner is to inhibit the unraveling and loosening of fragments, thus maintaining the rock mass integrity.

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 thin sprayed liners bridges joints, effectively penetrates fractures and bonds 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.

The trial application once again required the application of four Minova TSL products in order to determine the most suitable TSL for this environment. Four products were trialed.

1.3.1 Tekflex

1.3.1.1 Product description

Tekflex is a cement modified polymer membrane with very good flexibility, tensile properties and with excellent adhesive qualities. It forms a flexible support membrane that assists the rock to retain its initial integrity by reducing the adverse affects of scaling, spalling and weathering. It is a two component product generally supplied in a 20 litre bucket and when mixed together produces 15 litres of product that could theoretically cover $5m^2$ if applied to a flat surface 3mm thick. However, due to the roughness factor of the underground rock surface, it is estimated that $3m^2$ could be covered with one bucket.

1.3.1.2 Methodology

A Putzmeister RMP 1000 worm pump was used for mixing and pumping and the product was sprayed using an Ictus 406 spray nozzle. Before mixing and spraying operations commenced, the pump was filled with water and pumped to lubricate the hose and at the same time used to remove excess dust from the surface to be sprayed.

The contents of two buckets were mixed together for approximately 5 minutes and then pumped through a 1" hose from where it was sprayed onto the hanging and sidewalls. The total cycle from mixing to application took approximately 8.5 minutes. Due to the height of the excavation, a scaffold was used to access the hanging wall. The compressed air pressure was low; however the test was completed with the following results:

- An area of approximately 45 m^2 was covered with Tekflex and took 65 min to complete i.e. from start of mixing to end of spray (a single mix pumping unit was used)
- Rebound is not ideal as product drips down if applied too thickly in one spray pass
- Tekflex was touch dry in about 35 minutes from the time of application
- The cleaning of the pumps is laborious due to the sticky nature of the product

Fig 5: Tekflex being sprayed underground

1.3.2 Capcem KT

1.3.2.1 Product description

Capcem KT White and Grey have very similar properties and are supplied as a single component powder 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 grey finish. Capcem KT Fast is a new product developed by Minova with the intention to provide early aerial support coverage to underground excavations.

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 produces 17 litres of product when mixed with 5.4 litres of water. 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 2m^2 can be covered by one 25 kg bag.

1.3.2.2 Methodology

Capcem KT White

The same methodology was used as described above for Tekflex. The contents of three 25 kg bags of Capcem KT White were mixed together for approximately 4 minutes and then pumped through a 1" hose from where it was sprayed onto the hanging and sidewalls. The total cycle from mixing to application took approximately 7.5 minutes. The following results were achieved:

- An area of approximately 24 m^2 was covered
- Capcem KT White is easy to apply and penetrates very well into fractures
- Rebound is negligible so it can be applied fairly thickly in one spray pass
- Capcem KT White was touch dry in about 30 minutes from the time of application
- The cleaning of the pump is easy due to the nature of the product

Capcem KT Grey

The same methodology was used as described above for Capcem KT White and 9 bags of KT Grey were applied to the sidewall with the following results:

- An area of approximately 18 m^2 was covered and took 20 minutes to complete
- Capcem KT Grey is easy to apply and penetrates very well into fractures
- Rebound is negligible so it can be applied fairly thickly in one spray pass
- Capcem KT Grey was touch dry in about 30 minutes from the time of application
- The cleaning of the pump is easy due to the nature of the product

Capcem KT Fast

The same methodology was used as described above for Capcem KT White.
6 bags of KT Fast were applied to the sidewall with the following results:

- An area of approximately 12 m^2 was covered and took 15 minutes to complete
- Capcem KT Fast is easy to apply and penetrates very well into fractures
- Rebound is negligible so it can be applied fairly thickly in one spray pass
- Capcem KT Fast was touch dry in about 15 minutes from the time of application
- The cleaning of the pump is easy due to the nature of the product

1.3.3 Product Comparisons

Description	**Shotcrete** (±25 mm)	**Tekflex** (±3 mm)	**KT White** (±5 mm)	**KT Grey** (±5 mm)	**KT Fast** (±5 mm)
Approximate ex factory product cost per m^2	R 65.63	R 105.64	R 75.11	R 55.34	R 75.11
Approximate dedicated labour cost per m^2	R 90.25	R 55.00	R 55.00	R 55.00	R 55.00
*** Approximate Total cost per m^2**	**R 155.88**	**R 160.64**	**R 130.11**	**R 110.34**	**R 130.11**
Rebound	Poor	Average	Excellent	Excellent	Excellent
Bags per m2 Kg per m2	3.5 88	0.33 6.5	0.5 12.5	0.5 12.5	0.5 12.5
Ease of Application	Cumbersome	Difficult	Easy	Easy	Easy
**Time to cover 45 m^2 (conventional application)	150 Minutes	65 Minutes	55 Minutes	55 Minutes	55 Minutes
Equipment	Large	Small	Small	Small	Small
Interference with development cycle	High	Minimal	Minimal	Minimal	Minimal

* 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 part of the development crew.
** With continuous mixing arrangement of the TSL products, the application time can be limited to 30 minutes per approximately 45 m² application. Minova 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 Thin Sprayed Liners will ensure minimal interference with the development cycle and improve safety and productivity. The equipment required for Thin Sprayed Liners are small when compared to conventional shotcrete equipment and can readily be moved between sites. There are various types of Thin Sprayed Liner pumping and mixing equipment available, however the use of equipment with independent mixing and pumping arrangements is recommended to reduce application cycle times.

Fig 6: Minova Tekflex Equipment

1.3.5 Logistics

In the case of 25mm shotcrete, approximately 158 x 25 kg bags are required to cover an area of 45 m^2, which equates to ±4 material cars in an average deep gold or platinum mine. In the case of 5 mm Thin Sprayed Liners such as Capcem KT, 23 x 25kg bags are required to cover 45 m^2, which equates to only ±half the capacity of a material car in an average deep gold or platinum mine.

The use of Thin Sprayed Liners can therefor 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 development cycle might consist of the following:

- Cleaning operations
- Installation of temporary support
- Marking off support holes
- Drilling and installation of support
- Marking off of the round
- Drilling the round
- Charging up and blasting
- Re-entry and making safe

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.

Allowance must be made in the production cycle for at least half an hour for the application of the thin sprayed liner assuming the product and equipment is on site. This excludes the time taken to setup the equipment and the cleaning afterwards. Furthermore, it could be advantagous 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 Conclusions

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. Thin Sprayed Liners offer the means to prevent unravelling of friable ground, and thus can prevent the smaller fallouts of the rock mass between the support tendons.

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

2. PURPOSE-MADE PRODUCTS AND APPLICATIONS

The need to protect various rock types against weather induced deterioration has been acknowledged and indeed practiced for many years. Most prominently affected is the underground diamond mining industry where certain Kimberlites are notorious for their degradation on contact with moisture. Modern mechanized block caving systems have exacerbated the problem due to their need to develop many kilometers of tunnels in Kimberlites which have to remain stable for long periods of time. High speed multiple end development has also added to the problem in that any application of sealant must be quick so that it does not interfere with the mining cycle, and the product must be fast setting to avoid damage from other operations and also offer early support and withstand blast damage.

The majority of current TSL's are two part products which require mixing on site prior to application. The volumes required are much less than conventional shotcrete and offer logistical benefits. The mixing units are also small in comparison and can be moved easily from working one face to another. The equipment is realitively easy to clean. Having small equipment assists in reducing traffic congestion observed by larger equipment such as for shotcrete.

It was because of the importance of the above factors that Minova RSA developed a system that could help the typical kimberlite diamond mines to alleviate these problems.

2.1 DEVELOPMENT OF A UTSL (ULTRA THIN SPRAYED LINER)

From the above it can be concluded that the major problems in current TSL systems evolve around:

- Volume of material
- Mixing on site
- Cumbersome application equipment.

In the event that these could be removed then a much more user friendly and effective system could be developed. In order to achieve this, the following targets were set for the development team:

- Source a one part product which would not require on site mixing, can easily be sprayed and is fast setting (20-30 minutes)
- Application equipment should be portable by one person, preferably hand operated and easy to clean.

2.1.1 Product selection criteria

Typically the product should:

- Bond with both Kimberlite and shotcrete
- Provide a weather protection as well as preventing ingress of water from the overlying shotcrete
- If possible it should be water based to simplify cleaning of the equipment but not contain any free water which could damage the Kimberlite
- In order to comply with the low volume and portable spray equipment requirements the thickness of skin applied must be thin hence the name UTSL
- Have a very low viscosity to enable it to atomize through the hand operated spray equipment
- Comply with mine safety standards.

2.1.2 Selection of new product

The search started with discussions with the manufacturers of the various products already in use for the polymer liquids used in current TSL formulations. As each potential product was located a test sample was made by completely sealing a small section of Kimberlite and immersing it in water. After a few weeks each sample was taken from the water and checked for damage. The results were very clear; in some cases the rock had completely broken down to silt, others had some water damage whilst one or two samples were completely intact. These good samples were then subjected to further tests such as setting times in various temperatures and humidity, strength of skin formed if any, bond to surface and of course ease of spraying. After completing lengthy empirical trials, two products were chosen for larger scale application tests. The two products had similar characteristics with the exception that one readily formed a very strong elastic skin whilst the other penetrated the rock and only formed a skin if applied quite thickly. Both however appeared to provide similar levels of protection.

2.1.3 Selection of application equipment

In line with our wish list, the first unit tried was a chemical back pack spray unit as used in agriculture. Tthis certainly met all of our criteria in that it was hand operated, had sufficient capacity to completely seal an average end when blasted, was totally portable and provided no obstacle to the mining cycle. Initial trials went well, but it soon became apparent that with continuous use the product gelled in various places including the small pump unit and particularly the fine nozzle. Whilst these were minor problems and easily cleared they became an irritant to the operators who tired from operating the pump and dumped them in favour of a small compressed air unit. This had the disadvantage of course of needing a compressed air supply hose, but despite this quickly found favour with the operators.

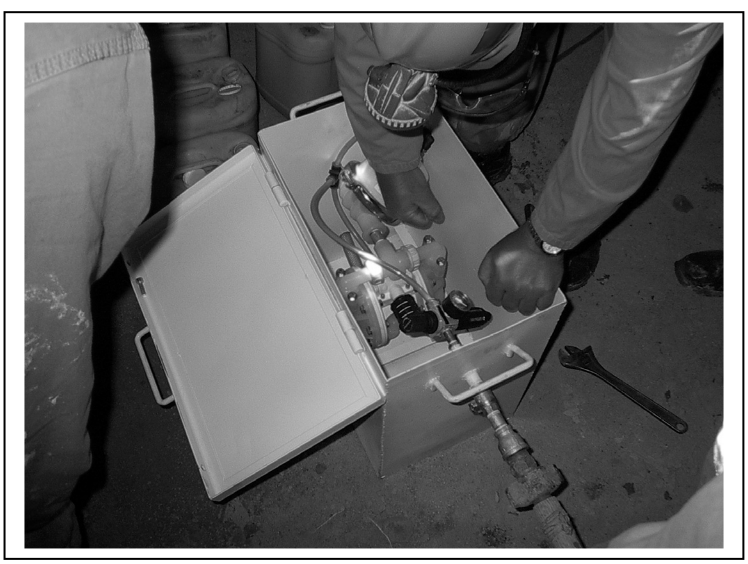

Fig 7: Rapseal Pump

2.1.4 System performance

The acceptance of the small air operated pump immediately made an enormous difference to the system efficiency. The added pressure at the nozzle meant that a long lance could be used to provide extra reach whilst still maintaining a good spray from the nozzle. The benefit of the long spray nozzle was two fold in that, firstly all spraying could be done with the operator standing on the floor with no scaffolding required and, secondly, unsupported areas could be sealed with the operator standing in a safe place. Sealing of freshly blasted ends was able to be done immediately after making safe and a typical end could easily be sealed in less than 10 minutes.

Fig 8: Rapseal Being Sprayed

The product now named Rapseal is in its natural state colourless and as such rather difficult to see on the rock. This was clearly a problem for the operator who found difficulty in ensuring a total area cover. The problem was overcome by including a dye in the formulation which then showed the sprayed product as a pink film on the rock. Application thickness was targeted to be 0.25 mm but this was not always easy to maintain particularly when spraying very uneven surfaces which required spraying from various angles to ensure complete cover. Setting time was slightly variable depending on temperature and humidity but the film was generally dry to the touch in 20 to 30 minutes.

2.1.5 Conclusion

Rapseal was designed purely as a sealant with the objective of reducing moisture ingress or egress into the Kimberlite. Tests and subsequent production use have proven its ability to do this. Practice has also shown that it has a positive influence on the bonding of shotcrete applied over it as a permanent support. Encouraged by the success of Rapseal as a pure sealant our chemists are now working on a derivative which will offer both weather protection and support.

2.2 AN EXAMPLE OF A SPECIALIZED APPLICATION METHOD OF TSL'S

In South African underground mines, it is common practice to use raise bored holes as airways between working levels. These raises vary in both diameter (1-4 metres) and depth (50-150 metres). The rock in which these raises are bored (Norite, Quartzite or Kimberlite etc) is very susceptible to weathering and eventual collapse. Support and protection of such holes has always been problematic both from a technical and safety point of view – the normal procedure has been to put men into the hole to support with rock bolts, mesh and shotcrete.
The challenge was posed to Minova RSA to develop a solution of supporting and protecting these raises without requiring personnel to work inside the holes. An innovative solution was devised using Minova's TSL Tekflex as the support and protection medium. The product application was unique in that, as opposed to spraying, the Tekflex was applied to the walls of these raises by means of a spinning disc.

2.2.1 Equipment

The disc was mounted on a three legged carriage, named the Spinnekop (Afrikaans word for Spider) which could be lowered and raised through the length of the hole whilst suspended from a variable speed hoist. This carriage was unique and had to be designed and built from scratch for this application.

After a small scale trial on surface in a large diameter steel pipe to prove the concept, an underground trial was done in a small borehole (1.4 m x 50 m) using a prototype Spinnekop carriage. Although the concept was proven successful with this underground trial, the following were identified as being critical before the larger holes (3.2 m x 150 m) could be attempted:

- Lighting at station and inside the hole
- Logistics to be sorted out in advance
- Variable speed controls on disc and winch
- Continuous mixing of correct quantity of product
- Video cameras to see what was happening in the hole
- Pulleys on headgear to help feed hoses and cables
- Headgear height - safety doors to open under the Spinnekop
- A dry-run should be done to make sure that everything is operating well

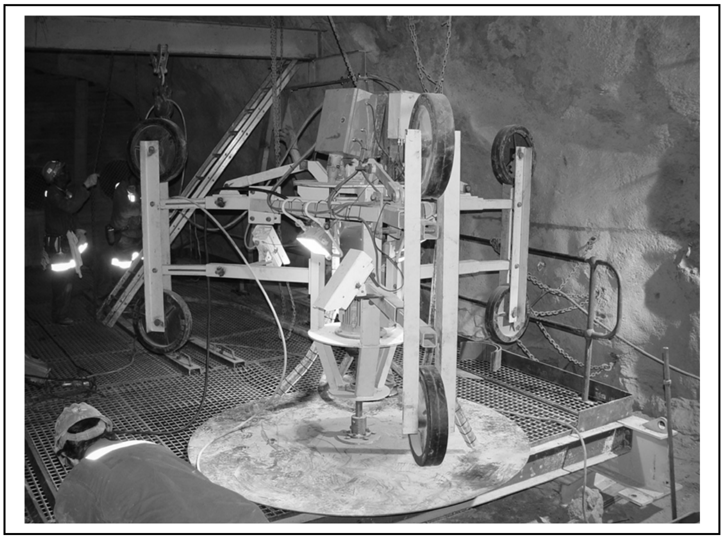

Fig 9: "Spinnekop" carriage ready to be lowered into the bore hole

2.2.2 Application

Tekflex was mixed conventionally at the top station and pumped via a rubber hose onto the spinning disc. In operation, the carriage is lowered to the bottom of the hole, with the hose and cables being clamped at intervals to the hoist cable using specifically designed quick release clamps. Two cameras were mounted on the carriage frame and information from these fed back to a monitor at the hoist station where the operator was able to maintain a visual check on proceedings at the application point.

The applied thickness of the Tekflex was controlled by adjusting the hoisting speed of the carriage in relation to the pumping rate of the product. The projection speed of the product from the disc is controlled by adjusting the rotation speed of the disc.

Because the required thickness of the final applied product necessitated two runs, it was decided to do the first run with the standard white product, and the second run with a brown variation. The rotation direction of the disc was reversed with the second run as well – this ensured a very good cover of the slight roughness on the side walls created by the raise borer head. The TSL skin created with each run was about 4.0 mm.

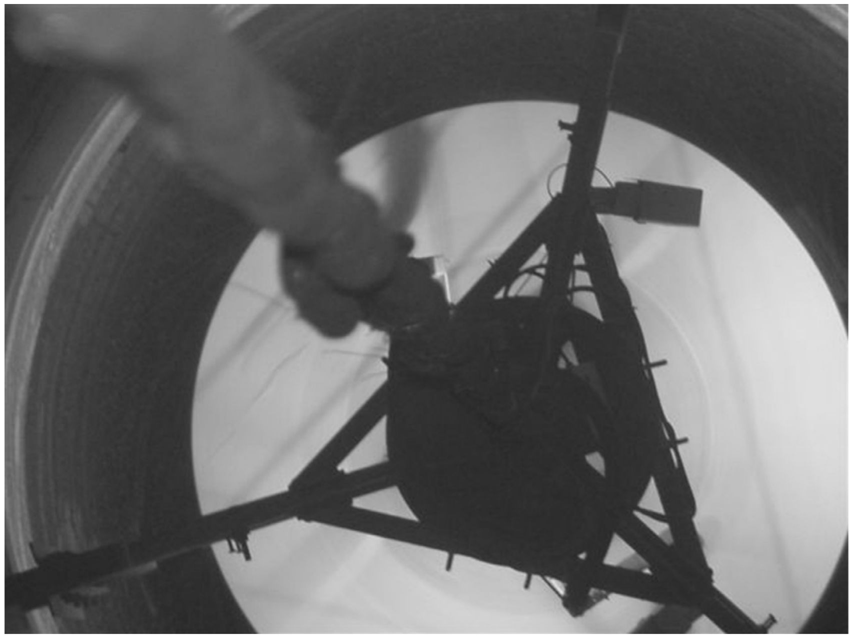

Fig 10: Photo of "Spinnekop" taken from the top of the borehole

2.2.3 Conclusion

The project team comprising people from both Minova RSA and the mine agreed that the Spinnekop project was a huge success. To date, two boreholes have been attempted and successfully lined at this particular mine. Furthermore, approval has been given and orders have been received to do several boreholes at one of the other large block cave diamond mines in South Africa.

The next step in the development of the Spinnekop system will be to adapt the system and equipment in such a way that it can successfully be applied in inclined boreholes as well.

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