THE NEW GENERATION POLYESTER RESIN CAPSULE SUPPORT FOR ROCK BOLT SOLUTIONS TO THE MINING INDUSTRY

W Snyman, P H Ferreira, D O'Connor
Minova RSA

Abstract

The development and progress of this support methodology within the underground mining environment is unique in its human ergonomic approach and lends itself to improved productivity in an industry where timing is essential. It is our intention to relate some facts to our vision.

As mining has progressed over the years, so has the development of support evolved. We have got to the stage where mining in South Africa has to compete with the international market as well as all the national competitors.

As part of a solution, Minova RSA, part of Minova and Orica International, has developed and trialled a new generation polyester resin support system which when coupled with a bolt allows ease of installation of a systematic roof support methodology that reduces the range of human errors seen to creep into many other systems and attempts to be almost foolproof.

Although resin was previously considered as the expensive route of supporting the hanging-wall / roof it has in the last few years become a relatively cheaper form of support compared to other systems and offers immediate support.

The advantages of a new resin are becoming more obvious and this methodology could soon be seen as a household name in mining support, i.e. Spin-to-Stall and TOO-SPEEDIE® resin capsules.

Both the technological breakthrough and the operational ergonomics of this resin / bolt system have reduced installation times and also incorrect installations are minimised if not totally removed. Additionally, the setting time ensures that the underground teams operate more effectively in a safer environment.

The competitive pressures as well as the need to make our mines a safer working environment with a Zero Harm attitude will continually play a role in the development of better products, both from a client and supplier perspective.

This paper will discuss the new generation resin capsule and bolt support system, and evaluate the advantages and disadvantages of such system in the mining industry.

Introduction

Ground support in underground mines specifically in South Africa, has become more important in order to meet industry and Department of Mineral Resources (DMR) requirements by 2013. The support methods and support types are being addressed in earnest to attempt to minimise fall of ground and related injuries in our mines.
Minova RSA, as part of Orica International, has developed and trialled a new generation polyester resin capsule support system, which, when coupled with a bolt allows ease of installation of a systematic roof support methodology and reduces the range of human errors seen to creep into many other support systems.

Resin capsule support is considered as the expensive route of supporting mining excavations which is true, but not without its related benefits. It has in the last few years become a more cost effective form of support compared to other systems and attempts to virtually offer a foolproof installation system.

Both the technological breakthrough and the operational ergonomics of this resin / bolt system have made that installation times are reduced and incorrect installations are minimised if not totally removed. Additionally, the setting time ensures that the underground teams operate more effectively in a safer environment.

The competitive pressures as well as the need to make our mines a safer working environment with a Zero Harm attitude will continually play a role in the development of better products, both from a client and supplier perspective.

The Background - Mining Statistical Information

In 2003 the mining industry and the DMR (then the Department of Minerals and Energy) set safety improvement targets to bring SA mine safety up to the level of international benchmark countries by 2013. The DMR reports describe the status of the mining industry safety in recent years. Although there has been a general decrease in accidents as shown in Figure 1, the rate of progress is not sufficient to reach the 2013 Milestone targets. This emphasises that achieving the "Zero Harm" concept requires new approaches, not just additional effort.

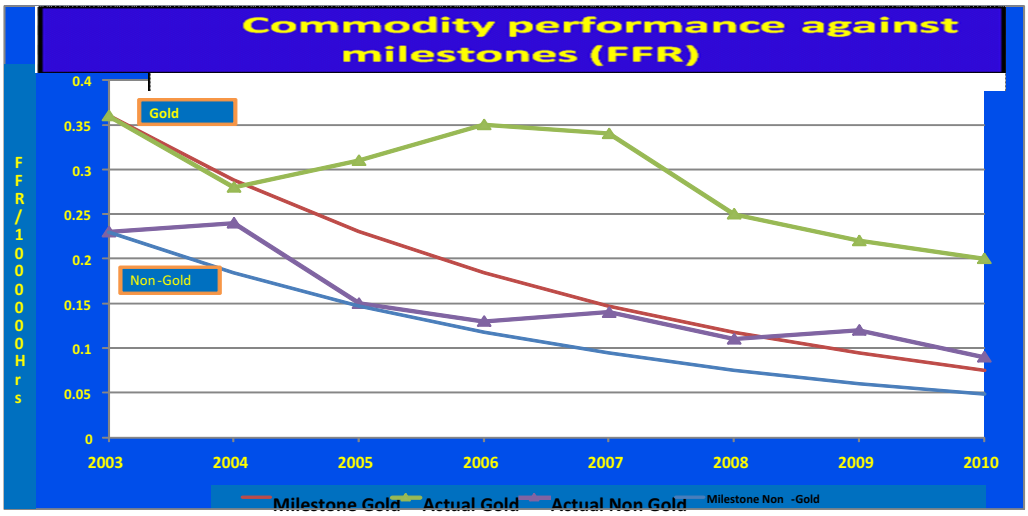

Figure 1

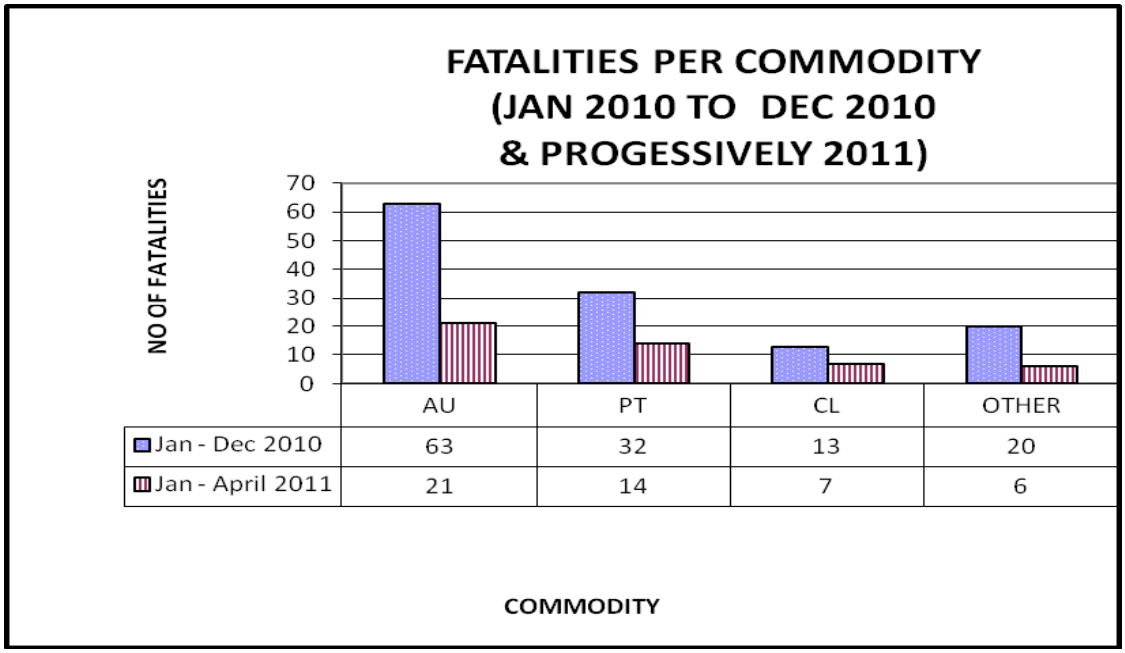

Figure 2

Figure 2 shows the fatalities for the various commodities in 2010, with the Gold mines indicating the need for a more asserted effort.

Figure 3 below shows the 2009 Rock related accidents of which the hanging wall gravity related accidents are some 60% of the total.

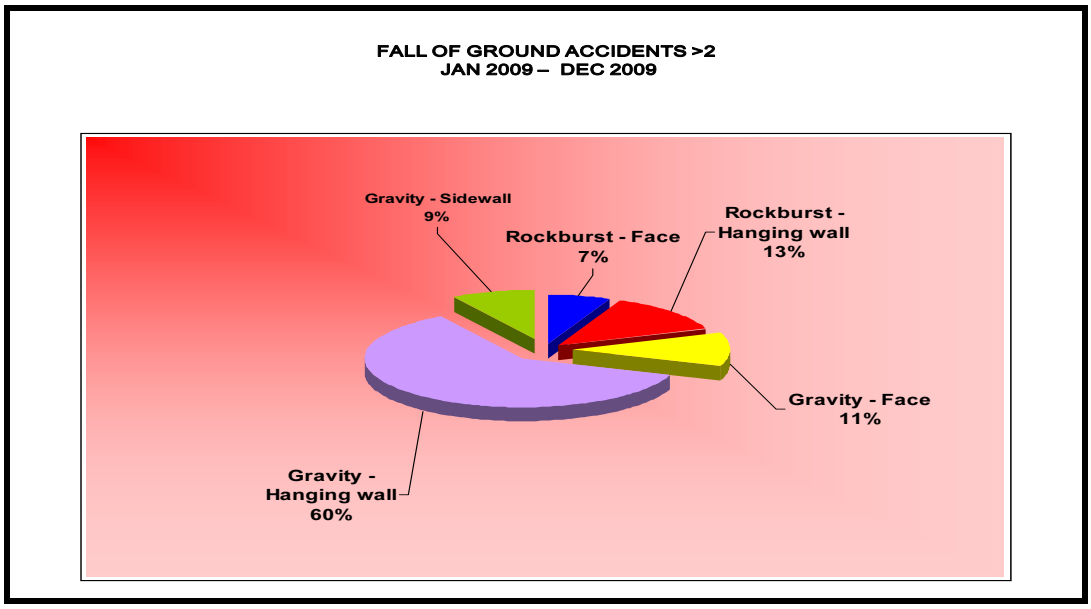

Figure 3

The 2010 – 2011 periods has shown a reduction in FOG's with only 27% of the total.

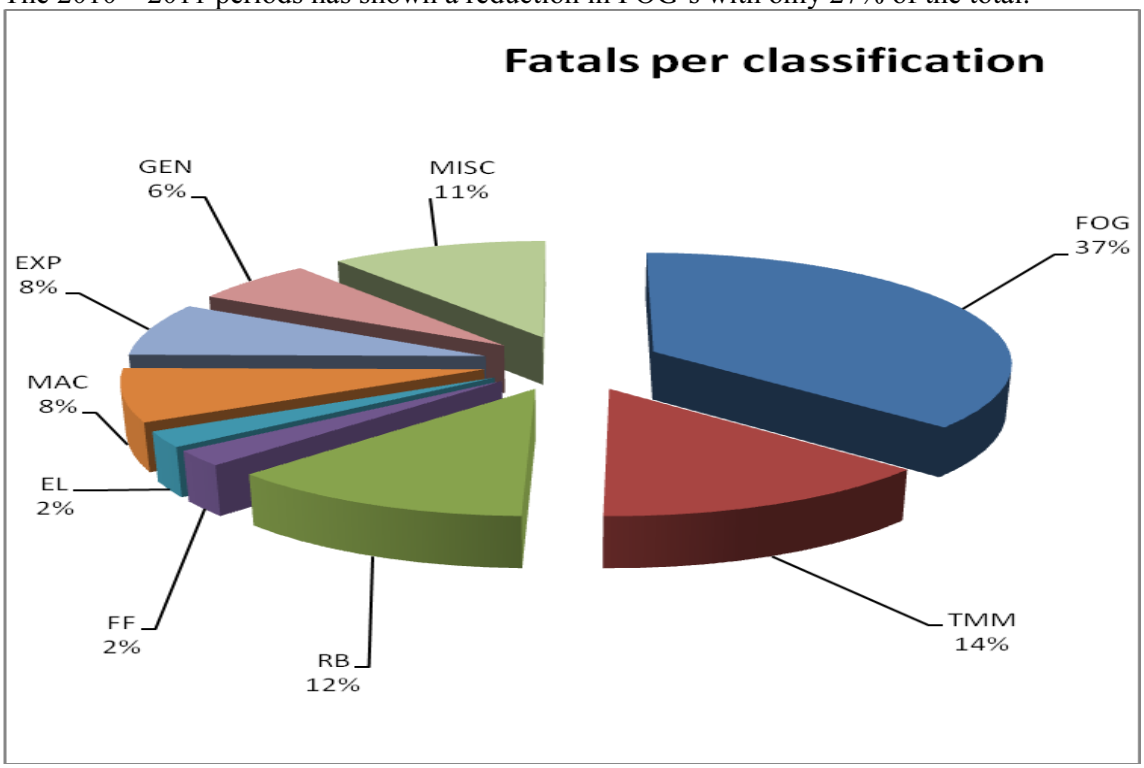

Figure 4

General, Miscellaneous, Fall of Ground, Trackless Mining Method, Rail bound, Fall from Heights, Electrical, Machinery, Explosives.

The statistics show that fall of ground accidents remain a significant problem. Driving improvement towards a fully safe working environment requires serious reduction in gravity falls from hanging-wall, as well as safer roofbolting activity.

Underground experience is that some of the incidents and accidents come from rocks falling from between the support units or whilst barring, hence emphasis on making safe procedures is also needed. The best hope for a sustained and rapid decrease in fall of ground accidents is widespread adoption good practices and use of the best available support systems.

For nearly 30 years, polyester resin capsules and rock bolts have been the general mode of rock support in SA coal mines. The system has been optimised for this environment; good practices have evolved and the results have put the coal sector ahead of the rest (Figure 2). Extending the benefits of resin-grouted rockbolting into the hard rock mines has required adaptations to the bolting system, which will be the subject of this paper. In the process, further improvements were also achieved in coal-mine rockbolting.

New Generation Resin Rockbolting

Comparison of the coal mining and hard-rock mining environments in SA showed the following differences that needed to be addressed for transfer of resin-bolting technology:

- Rock density is higher – 2700 kg/m3 in gold to 3200 kg/m3 in platinum mines versus 1400 – 2500 kg/m3 in the coal measures. Each bolt therefore has to carry a larger load when functioning in suspension mode;

- Hole diameters are generally larger (>30 mm) than in coal (<27 mm), due to the difficulty in drilling small holes with percussion drills. Resin capsule performance is adversely affected by increasing the bolt-hole annulus. This had to be compensated for to obtain equivalent performance;

- Many bolts in the hard-rock mines are still installed using hand-held airlegs with limited thrust (<3 kN), whereas coal bolting is done almost entirely with bolters having thrust exceeding 15 kN. A resin composition needing lower insertion force was needed;

- Similarly, the low torque and rotation speed of pneumatic percussion drills (<80 Nm and <200 rpm respectively) relative to coal-mine roofbolters (up to 250 Nm and >250 rpm) required greater attention to in-hole mixing of the resin capsules;

- Rock and ambient temperatures in hard mines are higher than the 20°C or lower normally found in SA coal mines, so actual setting times had to be adjusted. For example, "15-second" setting time resin used in a coal mines had be replaced with "20 second" (at 20°C) for hard-rock mines.

- The low stoping widths (<2 m) found in SA gold and platinum mines make logistics and material handling more difficult so reduction in number of components was desirable.

In 2009 Minova RSA initiated a research and development programme aimed at making resin rockbolting a viable support means for general use in gold and platinum mines. Most of the work to date has concentrated on platinum but the results are transferrable to gold mining as well.

The differences set out above required addressing the following aspects of resin capsule construction and application:

- Chemical formulation, encompassing strength increase and slowing of setting time while retaining the fast-cure characteristic needed for "spin-to-stall" systems;

- Capsule theology, to make the liquid resin more easily penetrated by the bar, without running out of the hole;

- Extending the application of the "spin-to-stall" method from highly mechanised and optimised coal rock bolting to semi-mechanised hard rock mining, with much larger resin annulus than previously considered possible. "Spin-to-stall" was considered an essential simplification of resin bolt installation to reduce the risk of incorrect methods being used in the more varied hard-rock environment.

- Combining the "spin-to-stall" chemical technology with "two-speed" capsule technology so that transport and insertion of multiple resin capsules could be replaced by insertion of a single capsule.

These developments went in parallel with increasing the use of mini-rigs, that made drilling rock bolt holes and installing bolts in the stopes less that 1.4 m high a safe, practical and economic process (O'Connor et al., 2008).

Chemical formulation changes

Reducing insertion force required reducing the mean grain size of the limestone filler particles from 600 microns to 200 microns. Normally the undesirable side-effect of this is a reduction of strength and an increase in cost. Careful optimisation of filler size grading, combined with change in the polyester resin molecular structure (proprietary) turned this around – strength increased (Figure 7) while cost remained essentially unchanged. Extension of setting time, from 15 seconds to 20 seconds (both measured at 20°C) for "spin-to-stall" was relatively simply achieved by adjustment of the accelerator loading.

Extension of "Spin-to-stall" technology

When "spin-to-stall" was introduced at Goedehoop colliery in 2000 (reference), it produced a radical simplification of resin rockbolting, combined with reduced cycle times and an overall improvement in bolting quality. Two technological changes underline the "spin-to-stall" method: very rapid cure of the resin from the time that it first starts to set and limitation of the

torque on the setting resin by use of shear-pin nuts that break out in a narrow range of torques. Bolting conditions at Goedehoop were nearly ideal - : a 20 mm bolt was used in a 27 mm hole and rotation speed was over 600 rpm. Average spinning time was 9 seconds for a nominal 15 second setting resin, showing that the resin was not being over-spun.

The rapid-cure resin was successfully incorporated into the modified chemical formulation described above, and the shear-pin nut could be used without change. However, there remained doubt as to whether "spin-to-stall" would work in the less-than-ideal circumstances of 20 mm bolts in 30-32 mm holes and rotation speeds well under 250 rpm (most in fact under 150 rpm) produced by installations using conventional pneumatic rockdrills. With no experience or theory to guide, the only way to resolve the doubt was by actual trials. Extensive trials were conducted in the Bushveld platinum mines and showed that adequate support resistance and stiffness were indeed obtained.

The advantages of "spin-to-stall" have thus been made available for resin bolting in hard rock.

Combined "spin-to-stall" and "two-speed" resin capsules

Two-speed resin capsules (one portion "fast" and the other portion "slow" setting) were developed originally in Australia and introduced in modified form to South Africa in 1999. The two-speed capsule replaces use of individual fast and slow capsules in tensioned bolted systems, making for easier logistics and faster hole loading. There is also less opportunity for the operator to insert fewer than the required number of capsules.

The modified two-speed capsules made in South Africa were manufactured by injecting accelerator into one end of the capsule while it was being formed. It was found that this method did not give adequate dispersion of the accelerator for the capsule to qualify for use in "spin-to-stall" applications. Consequently, the manufacturing process had to be extensively modified so that the accelerator is pre-dispersed asynchronously with capsule formation. The result is a two-speed capsule with a "fast" portion that cures fast enough to be used as "spin-to-stall".

Testing and qualification of the system

With all the elements in place, Minova RSA embarked on an extensive laboratory and field test programme to determine the performance of the system and identify the risks that needed to be managed to make it acceptable.

Effect of Annulus

Laboratory tests in internally-threaded steel pipes confirmed the conventional wisdom that optimal annulus is approximately 2 – 4 mm. However, the results for larger annuli (see Figure 5 below) show that even up to 7 mm annulus, there is substantial and stable strength. This is sufficient to meet geotechnical requirements, especially as regards stiffness.

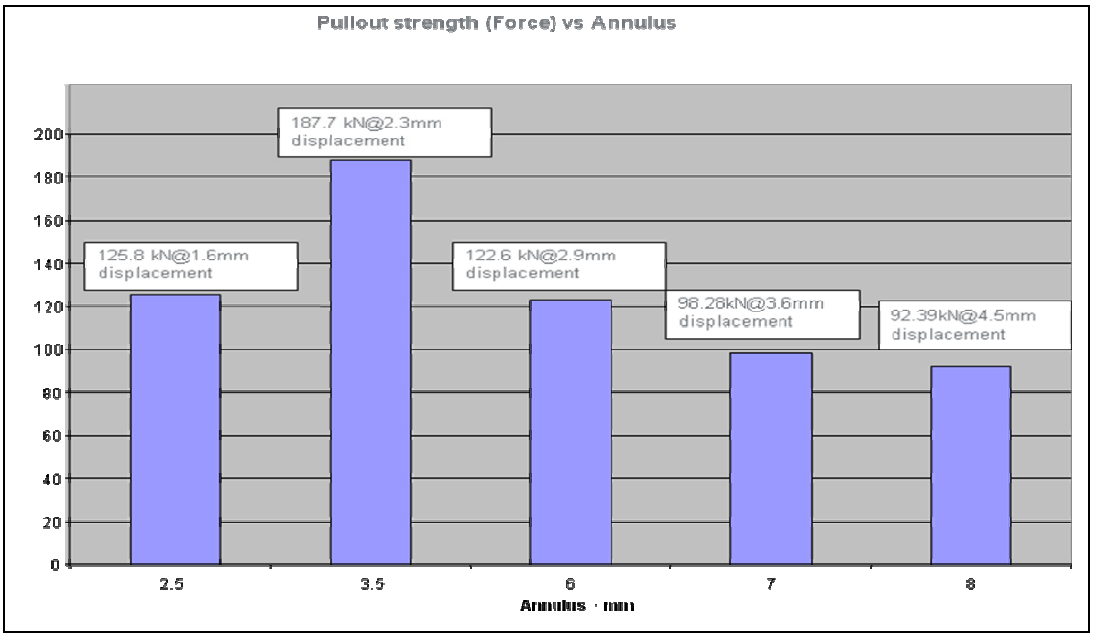

Figure 5

In Figure 6 below, tests were carried out at the Isando Resin laboratory.

Test 1 was stopped at 180kN, and Test 2 was taken further to differentiate and determine the deflection.

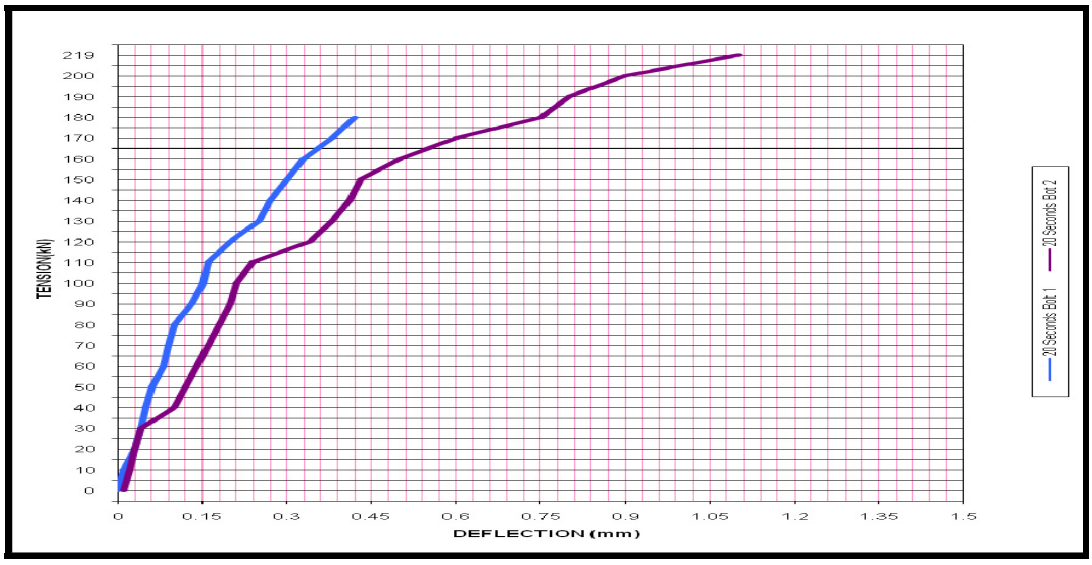

Figure 6

Strength

The revised formulation showed improved pull-out strength performance – see Figure 7 below.

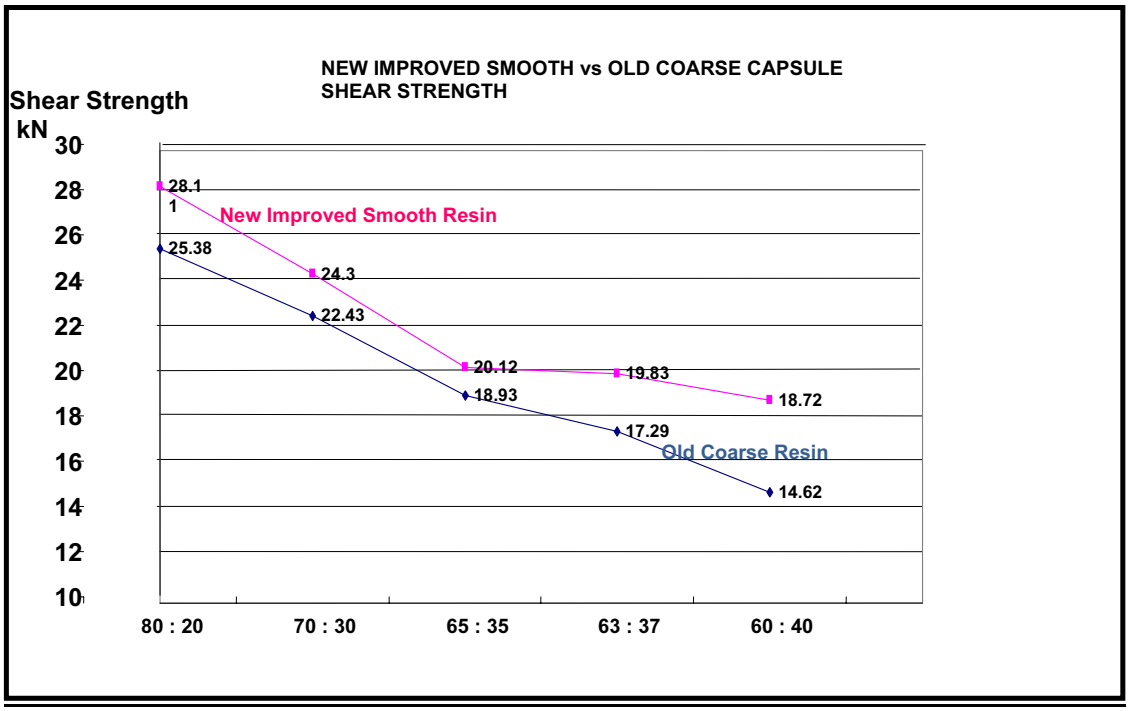

Figure 7

Setting times were tested relative to various temperatures for different mining conditions.

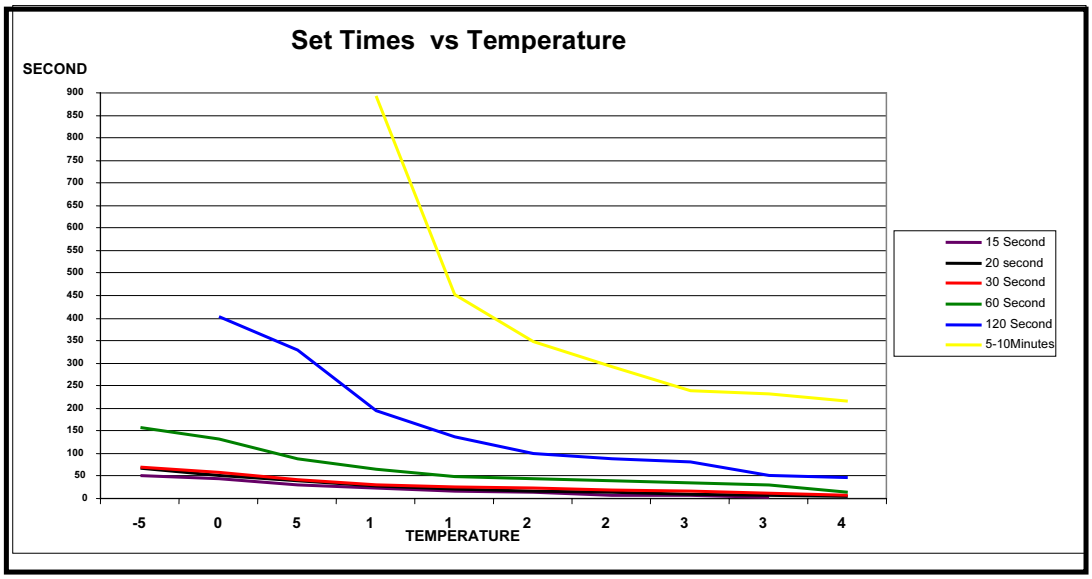

Figure 8

In figure 9 below, compressive strengths were compared to each other relative to time.

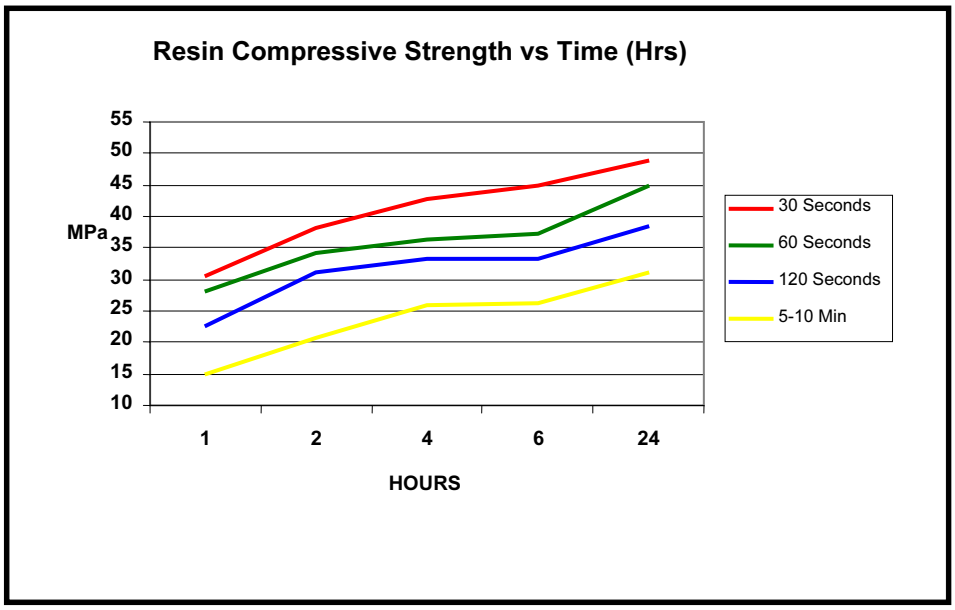

Figure 9

The various mixes were checked to determine optimum ranges and verify our current specifications.

In figure 10 below, short encapsulation tests were carried out at standard temperatures using widely used bolts in standard hole dimensions.

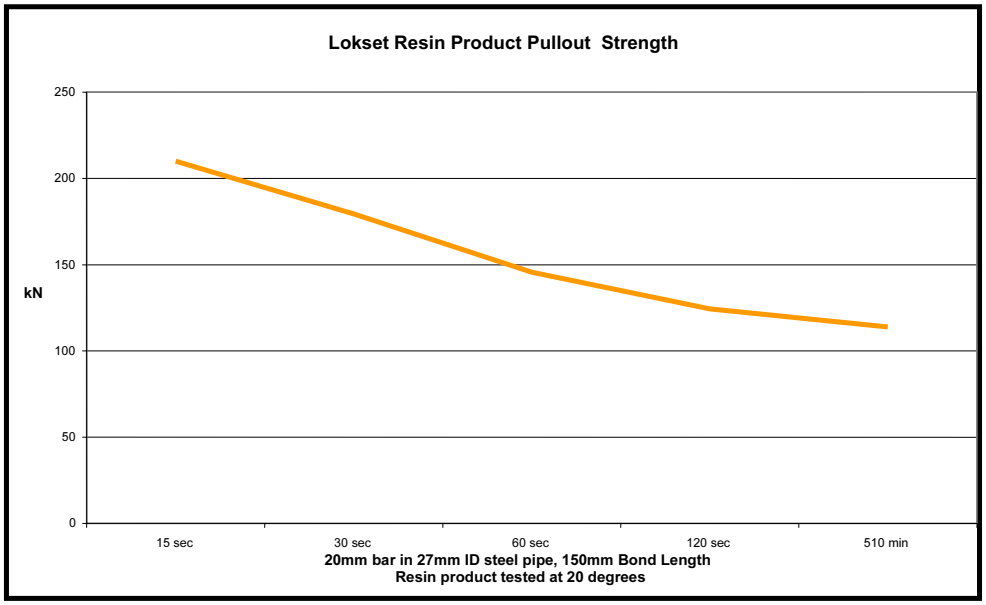

Figure 10

In addition to these tests, fire resistance testing has also been conducted to ensure adherence to standard practices.

The Fire lab report concluded that although the resin cartridges are combustible they self-extinguish when the external fire source is removed, thus rendering the resin as a product with minimal fire hazard.

The toxicity is within the limits i.e. below 5.0.

Field Trials

Several tests were carried out on the Platinum mines at the start to determine the practicality of the faster set times.

Spin-to-Stall results from tests conducted in December 2008				
Hole	Drill Time (min)	Spin-to-stall time (sec)	Result	Remarks
1	2.28	7	Fail	Set too quick
2	2.57	15	Pass	
3	2.50	24	Pass	
4	2.37	25	Pass	
5	2.20	41	Fail	Did not stall
6	2.39	18	Pass	
7	2.15	23	Pass	
8	2.28	46	Fail	Did not stall
9	2.27	40	Fail	Did not stall
10	2.32	15	Pass	

Figure 11

The development of the 20 second resin for spin to stall systems for hard rock was initiated after trials with 15 second resin and 30 second resin were not successful. This was a result of warmer rock temperature (up to 30°C) reported for hard rock strata. A new product was introduced with a set time between that of 15 second spin to stall resin and 30 second resin.

To achieve resin stall time ranging between 15–22 seconds (depending on temperature, shear pin breakout torque, etc), a 20 second spin to stall resin was formulated (set time 17-20sec @ 28°C).

The product was prepared as a combination of resin and standard catalyst and a number of lab tests were conducted to verify its performance. The resin mastic for the product is a Low insertion, meaning, contains fine fillers. A Low insertion product differs from a normal product by not having any coarse filler. For that reason, this product carries higher resin content in the mastic than normal and is available at 80:20 ratio of resin to catalyst in a capsule.

Along with the laboratory tests, field trials were done, with the following results:

Spin-to-Stall results from tests conducted in January 2009				
Hole	Drill Time (min)	Spin-to-stall time (sec)	Result	Remarks
1	1.42	18	Pass	
2	1.51	17	Pass	
3	1.38	24	Pass	
4	1.39	23	Pass	
5	2.00	20	Pass	
6	2.38	20	Pass	
7	1.57	22	Pass	
8	2.21	17	Pass	

Figure 12

Late 2009 tests on the product gave the following results:

Set time @ 20°C	19 sec	17 - 20 sec
Shear strength Mpa	26.07	> 25 Mpa

See Pullout strength results in Figure 13 below.

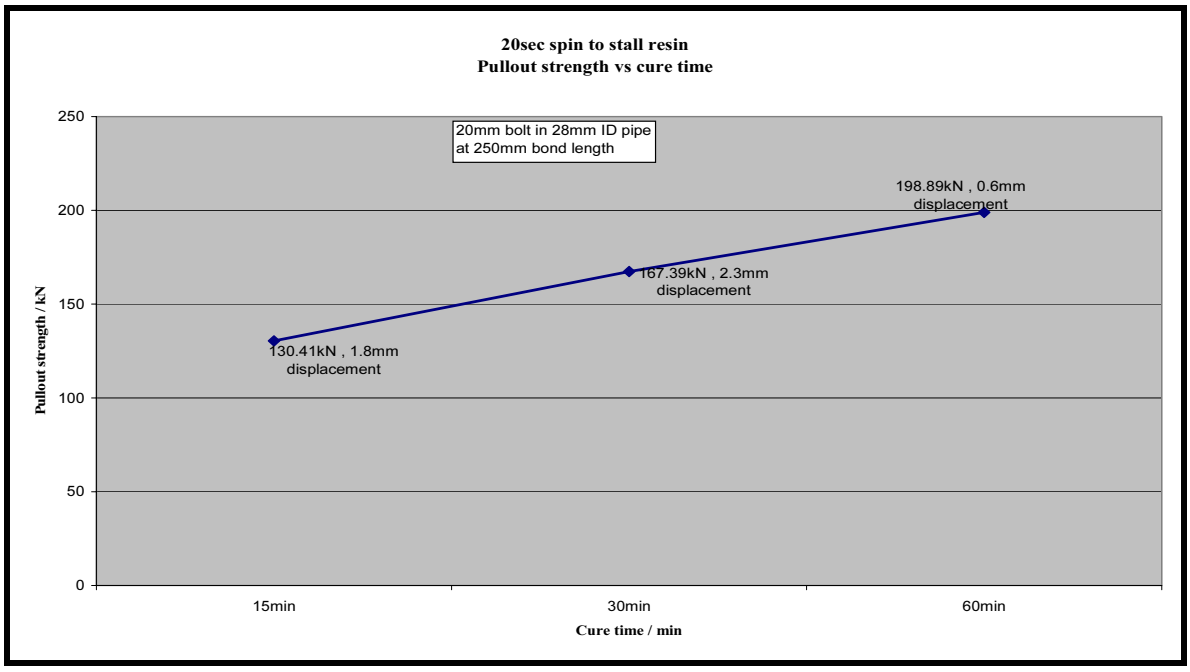

Figure 13

The Mining Environment

The Spin to Stall Resin has thus far been trialled and implemented in the shallower mining environments. This means general virgin vertical stress levels of less than 35 MPa, but with higher horizontal to vertical stress ratios (in some cases up to 1:1).

In essence shallow mining environments mean more focus on key block failure that causes unravelling, especially along geological structures that have been exposed due to tunnelling or mining.

Designing support systems need to incorporate rigidity to be effective in the creation of self supporting beams, especially for stope support, but also where the strata is thinly layered and tunnel orientation is on strike i.e. creation of cantilever beams. In this scenario, any geological feature may form triangular wedges that could potentially fail.

In stopes the existence of cross-bedding or anomalies such as potholes will require similar consideration.

When the shear strength of approximately 26 MPa is considered in an environment of 30 – 40 MPa induced stress where relaxation also takes place it must be thought that a rigid support unit system should maintain stability. In other words, it is the capacity of the support unit to directly counter balance the volume of rock requiring support.

Roll-out & Expansion into Market

Testing of this product is still an ongoing process as conditions on the different mines become more apparent. However, since introduction several mines have opted for this product as a solution to the ever increasing need to improve safety and productivity, whilst catering for increased depth and stress regimes.

Conclusion

It is evident that the change from the old to the new generation polyester resin has shown a measure of success. The continued development and search for improvements in this sphere of mining support must surely pave the way along with good bolting practice towards our Zero Harm environment.

The improved smooth polyester resin capsules along with Spin-to-Stall fast setting resin offers great strength. The TOO-SPEEDIE® system gives full column resin grout with correct hole, bolt size, break-out nut and load indicator and suitable washer. Both systems now offer a near foolproof bolt installation with improved safety due to the early active support as well as improved productivity through time saving per bolt installation.

References:

Department of Minerals and Resources, Occupational Health and Safety report, April 2011

Fire Lab report, Evaluation of small-scale fire properties of rock anchor resin system, May 2011

The Minova Guide to Resin Grouted Rockbolts - 2006

Authors

P H Ferreira – BSc. Eng (Mining) Wits Pr.Eng, AEP-Unisa, MDP-Unisa, DPLR-Unisa, FSAIMM, AAMMSA, ASACMA,SANIRE, Mine Manager's Certificates of Competencies Metalliferous & Coal

D O'Connor – BSc. Hons Geophysics, FSAIMM, SANIRE, MBA UCT

W Snyman – MSc. (Rock Eng) Wits, MSAIMM, SANIRE,