



Application of shotcrete at Oryx Mine

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Synopsis

When Oryx Mine down-scaled in 1994, focus was placed on development, with the primary aim being the exposure and proving of ore reserves. In order to achieve this aim, development ends had to be advanced to reef at the maximum possible rate. This in turn called for support methods which could keep up with the advancing faces, taking up minimum space and time for installation, while providing on the face areal coverage and effective long-term support. In the majority of the development ends which were located in fairly competent ground, the grouted rod development support proved to be adequate until such time as secondary support in the form of meshing and lacing could be installed.

The ends developing towards the eastern boundary of the mine, especially in the 'C' block, encountered extremely adverse ground conditions due to the presence of smectite zones within the footwall quartzites. Smectites are a group of montmorillonite clay materials, mainly composed of hydrous aluminosilicates. They occur as minute platy crystals in the rock mass and are especially notable for their ability to absorb liquids. Generally, the zones are found in between the bedding planes of the host rock, and may vary considerably in thickness over short distances.

Wherever the smectites were exposed by the development blasting, the rockwalls weathered as the smectites absorbed water and the condition of the tunnel rockwalls deteriorated rapidly. When the smectites were left exposed and allowed to weather, it became almost impossible to install secondary permanent support such as meshing and lacing at a later stage. To minimise the exposure time and subsequent deterioration of the smectite zones, it was recommended that all development ends encountering smectites be shotcreted as soon as possible after blasting.

In developing a shotcreting support methodology, both a drycreting and wetcreting system were investigated. The situation at the time ruled out the use of a wetcreting system on the basis of the extensive and costly infrastructure required, as well as its limited manoeuvrability. Instead, it was decided to opt for a smaller scale but more manoeuvrable drycreting system. The system utilized a number of portable drycrete machines with pre-bagged cement, which could support several development ends in close proximity. Initial trials using normal 30 MPa shotcrete on 19 level proved successful and the system was implemented.

Development end shotcreting

Shotcreting procedure

Six crews of five persons each were initially employed for development end shotcreting. The basic procedure consisted of applying a



Figure 1—Typical shotcrete application in development end

25 mm layer of shotcrete to the newly-exposed hanging- and side-walls of the excavation, then applying a second 25 mm layer to the area that had been supported the previous day. Where necessary, areas where fallout or blast damage had occurred were also resprayed. The shotcrete was supplied in 25 kilogram bags as a sand mixture with a separate small bag containing cement, which had to be mixed together before application. As there was insufficient space in the development ends for screw feeder/mixers, the two ingredients were simply mixed on the footwall using shovels before being tipped into the shotcrete machine hopper.

Problems and solutions

The major problems and subsequent solutions to date include:

- ▶ *Training the work force to apply shotcrete and operate the shotcrete machines.* Most of the workers had come from a production environment, with no previous experience of shotcreting. There were no training facilities for shotcreting and very little training time

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available. The solution was to conduct on the job training at the actual work site underground. The entire gang was trained at the same time, with the actual training process relying heavily on close supervision by the miner and shiftboss. As can be imagined, the learning curve was a steep one and the first few months were extremely hectic. Small, senseless accidents occurred regularly, which led to large numbers of special instructions being issued. These special instructions were in time incorporated into a proper training manual and training programme for shotcrete workers.

- ▶ *Shotcrete machine reliability and the time and cost of repairs by the supplier.* The shotcrete machines did not cope well with the harsh conditions that were encountered underground and their initial breakdown rate was extremely high. The problem was further compounded by the supplier being located in Germiston, which meant that the machines were sometimes off the mine for weeks at a time. In order to keep all the shotcrete gangs supplied, we had to resort to purchasing several additional spare machines. The high cost of having the machines serviced and repaired by the supplier, combined with the downtime involved, forced us to attempt the repairs ourselves. At first we sent the machines to the mine workshops, but we soon found that they were being shifted aside to make place for larger jobs. This meant that they were often unavailable for longer periods than if we had sent them to the supplier.

We eventually took one of the support shiftbosses who was mechanically inclined out from underground and sent him to the supplier to learn how to repair and maintain the shotcrete machines. On his return to the mine, he formed a shotcrete machine repair gang and they took over the repair and maintenance of the machines. This has been extremely successful, resulting in increased reliability and much less down time on the machines. The repair gang have also made a number of modifications to the machines, further increasing their robustness and reliability.

- ▶ *Material supply problems.* The layout of the shaft system, comprising a main and sub-shaft, meant longer shaft times and delays in getting material to the working face. Material cars were also not allocated to specific sections or levels, and the production sections got first pick of the cars. The solution was to allocate only side tippers to the shotcrete section. Not only did this solve the allocation problems, it also allowed the bagged shotcrete mix to be off-loaded faster than normal material cars, thus allowing more time to be spent actually shotcreting and ensuring a faster turn around time in getting the cars back to the station and up to surface for re-loading.
- ▶ *Creation of dust by the machines.* In the confines of development ends with forced ventilation, the dust created by the machines often resulted in low levels of visibility and difficulty in breathing. This in turn affected the quality of the shotcrete application. Numerous attempts were made at dust suppression, with limited success. These measures included varying

the moisture content of the shotcrete mix, changing the shotcrete mixes, using dust suppressing additives, different rotor shapes and various types and compositions of gaskets.

Most cases of excessive dust were, however, traced back to poor maintenance of the machines underground. Despite having been trained how to do basic repairs and maintenance underground, it seemed that the gangs simply were not interested in doing any more than the bare minimum. Disciplinary action could not be taken as it was impossible to pinpoint who the culprit was. The only effective way found to ensure correct maintenance of the machines was the creation of a special bonus, paid to a gang only if their machine had spent a certain time underground without needing any major repair. This scheme has proved so successful that some of the machines have spent more than a year underground to date.

- ▶ *Segregation of material due to the use of excessively long hoses.* In the drive for production, very few cubbies were laid out along the tunnels and those that were blasted were generally used for storage. Proper pipe and track equipping was also sometimes left far behind the advancing faces. The shotcrete machines and the shotcrete material, which were stored in cubbies, were at times 150 metres behind the advancing faces. As the shotcrete mix had to be conveyed in the hose over long distances, segregation was almost inevitable and the result was a poor quality application.

While the basic remedy was to ensure that cubbies were blasted regularly and kept open for the shotcrete machines and material, a 'quick fix' solution was to mount the machines on flat cars. These were stored well behind the working face and, when needed, pushed into the face together with the side tippers containing the shotcrete mix. At one stage the process was refined to the point where the shotcrete was mixed in the back area in a side tipper. When the flat car with the shotcrete machine and the side tippers were pushed into the face for use, a funnel was hooked onto the front end of the side tipper and the mix poured directly down this funnel into the shotcrete machine hopper.

- ▶ *Poor adhesion of the shotcrete to the rockwalls.* Some time after the development end shotcreting had begun, it was noticed that in numerous places the shotcrete was falling off the rockwalls. No signs of stress-induced rockwall slabbing were observed in these areas, but closer investigation revealed excessive dust on the underside of the fallen shotcrete slabs. A check on the work in progress also showed that the rockwalls were not being washed down before shotcreting began, obviously preventing proper adhesion of the shotcrete. A change in the work procedure to ensure the washing down of the rockwalls before shotcreting begins and strict supervision has virtually eliminated this problem. Although it may sound as if the shotcrete support system is nothing but a series of ongoing problems, most of the items mentioned above were merely teething problems and were quickly remedied. At present, Oryx Mine supports approximately 5000

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Figure 2—Example of poor shotcrete adhesion to the rockwalls

square metres of haulages per month using shotcrete with minimal problems other than those associated with day to day production.

Special applications

The success with the drycreting system in development ended formed the backbone of Oryx Mine's interest in shotcrete as a support medium. This in turn lead to our subsequent involvement with the SRK Shotcrete working group and experimentation with new developments in shotcrete technology.

Although the applications used on Oryx Mine differ from the basic aims of the SRK working group, the application of the technology used and results obtained by the working group proved to be worthwhile.

Mesh reinforced shotcrete

During a routine visit in 1995 members of the Rock Engineering department discovered that several areas in the main return airways were scaling excessively. If the scaling were to continue, it would result in ventilation restrictions and, in the long term, the loss of the return airways. Further



Figure 3—Area in return airway supported with mesh reinforced shotcrete

investigation revealed that although the areas in question were being affected by weathering rather than stress-induced failure, they would have to be supported.

The high temperatures and humidity levels in the return airways effectively negated the use of meshing and lacing as a support medium, unless it was shotcreted to prevent corrosion. The services had been stripped out of the return airways and re-equipping them to be able to drill holes for installing meshing and lacing would have been extremely costly. As some success had previously been achieved in the diamond mines with mesh reinforced shotcrete, it was decided to attempt the use of this support system in the return airways.

The basic procedure in this case was to apply a 25 mm layer of shotcrete to the rockwalls and leave this until dry. Diamond mesh would then be stapled to the shotcrete using a spring loaded Hilti gun. Finally the mesh would be sealed by a second 25 mm thick layer of shotcrete, ensuring no exposure of the mesh and thus no corrosion.

Although the mesh reinforced shotcrete appeared to be fairly effective as a support system, it was extremely time consuming to apply, as it required triple the amount of work of normal shotcrete. Uneven areas in particular proved to be a problem as the mesh would not lie flat against the first layer of shotcrete and excessive shotcrete had to be used for

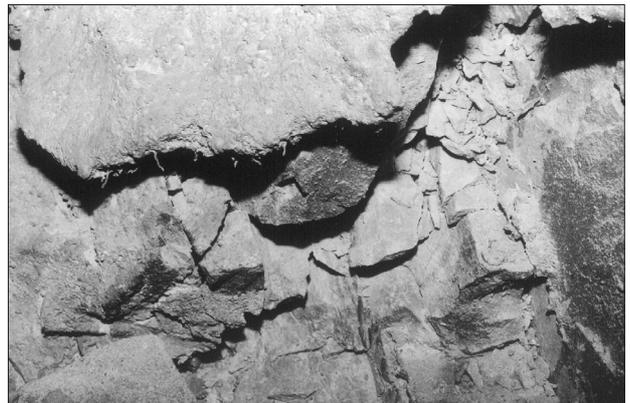


Figure 4—Example of steel fibre reinforced shotcrete - note steel fibres protruding from applied shotcrete



Figure 5—Area where corrosion of steel fibres has resulted in shotcrete breaking up

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the second layer. The concept of fibre reinforced shotcrete was thus greeted with much anticipation.

Steel fibre reinforced shotcrete

The first fibre reinforcing used at Oryx Mine was steel fibre. An extremely jointed major dyke was intersected by footwall drives in the northern block. There were two major joint sets in the dyke, both of which exhibited low cohesion levels across the joint surfaces. The size of the blocks created by the joint sets varied between 100 and 600 mm and the fallout rate was high, resulting in extremely poor and blocky ground conditions. Blocks simply fell out around the standard 1.0 m x 1.0 m pattern grouted development support and it was decided to shotcrete the rockwalls to give a greater areal coverage.

In an effort to increase the strength and deformation capability of the shotcrete, steel fibres were used as reinforcement. Major problems were encountered in this application, as listed.

- ▶ The low corrosion resistance of the steel fibres meant that they could not be premixed into the bagged shotcrete mix. Instead, like the cement, they were placed in a separate small plastic bag inside the main 25 kilogram bag, the intention being that the labourers mixing the shotcrete break open the two smaller bags and add the fibres, together with the cement, into the main mix, ensuring even distribution by correct mixing. Initial attempts to add the steel fibres to the rest of the mix on top of the shotcrete machine hopper resulted in numerous small wounds on the mixer's hands as the sharp Dramix fibres easily punctured the rubber gloves worn by the mixer. The gang was subsequently instructed to mix the ingredients together on the footwall and then tip the mixture into the shotcrete machine hopper.
- ▶ The Dramix fibres tended to cling together, so that despite the gang's attempts to ensure an even mix, they regularly formed an obstruction in either the machine or the hose. All work would then be stopped until the blockage had been found and removed. Enlargement of the size of the delivery port and the delivery hose partly solved the problem, but any bend or kink in the hose quickly blocked up.



Figure 6—Shaft headgear bin chamber supported by shotcrete reinforced with polypropylene fibres

- ▶ The wear rate on the shotcrete machine and hoses was much higher than normal. In the space of two months, the entire machine was replaced twice. Gaskets were replaced daily and hoses lasted no more than two weeks. Bends or kinks in the hoses, where higher friction occurred, wore through in less than a shift.

The combination of these factors was a sequence of delays, which were frustrating not only to the shotcrete gang but also to the production crew who had to wait for the end to be shotcreted before they could begin work in the face. It was soon discovered that the gang were not including the steel fibres into the shotcrete mix, or were including only enough not to block the machine. Despite disciplinary action being taken against the gang, the situation did not improve and the project was stopped.

Subsequent visits to the project sites revealed an abnormally high corrosion rate of the steel fibres. The expansion of the fibres caused by the corrosion, resulted in the shotcrete cracking up in places. In other areas the fibres had corroded through and were no longer contributing to the integrity of the support system. This phenomenon was also observed in another area where steel fibres had been used as a reinforcement above the settler dams. It is therefore recommended that future users of steel fibre reinforced shotcrete bear this in mind when shotcreting areas with high moisture and humidity levels.

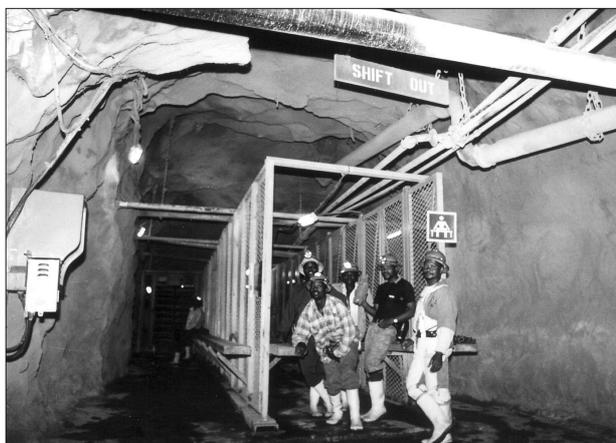


Figure 7—Shaft waiting place supported using polypropylene fibre reinforced shotcrete



Figure 8—Section of applied polypropylene fibre reinforced shotcrete

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Polypropylene fibre reinforced shotcrete

Following the disappointing results obtained with the steel fibres and the successes obtained by the SRK working group with monofilament polypropylene fibres, these were investigated as shotcrete reinforcement. Tests were done on the mine with the standard shotcrete machines using needle fibres and more flexible multifilament fibres. Better distributions were obtained with the needle fibres, provided the fibre length was restricted to no more than 60% of the delivery hose diameter.

Shortly after the tests had begun, management requested that the loading bin chamber in the sub-vertical shaft be supported, as it was showing signs of deterioration. The size and shape of the chamber ruled out the possibility of using meshing and lacing, so the choice of support fell to shotcrete. Because of the size and complexity of the job, it was decided to hire a larger shotcrete machine from one of the members of the SRK shotcrete working group, MASH Engineering. This machine had been designed for use with polypropylene fibres and incorporated a number of unique features, including a built-in pre-mixer/feeder. It had previously been used for testing purposes by the working group. MASH Engineering also supplied the pre-bagged shotcrete mix.

Both the machine and the polypropylene fibre reinforced shotcrete performed very well under the circumstances. There were no major breakdowns, rebound from the specific shotcrete mix was lower than that of normal shotcrete and virtually no dust was created during the shotcreting process.

Delays in available working time meant that the job took

longer than expected and the machine had to be returned. A second scheduled job, the support of a large waiting area, could not be completed. As there were still a number of bags of MASH Engineering shotcrete mix left over we decided to try them with the standard shotcrete machines, rather than waste them. To our surprise the combination worked perfectly and we were able to finish the job using the polypropylene fibre reinforced shotcrete.

Future application

Our aim for the future is increasing the use of shotcrete as a support system in place of meshing and lacing. Examples of this include:

- ▶ The support of excavations with high moisture and humidity levels, such as return airways, using fibre, rather than mesh as reinforcing.
- ▶ The support of crosscuts to reef. If we are able to destress a crosscut quickly enough to limit deformations to a minimum, then a support system consisting of development grouted rod support and fibre reinforced shotcrete should prove to be adequate.
- ▶ The support of large chambers in cases where minimum stress changes are anticipated.

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OBITUARIES

		<u>Date of Election</u>	<u>Date Deceased</u>
B.D. McNeice	Retired Fellow	18 March 1968	
J. Pope	Retired Fellow	8 August 1947	11 March 1998
W.H. Bailie	Retired Member	12 September 1952	25 March 1998
A.J. Rossouw	Retired Fellow	11 November 1960	18 April 1998
E.P. Gush	Member	11 March 1960	8 May 1998

Visit to BAUMA*

There is only one way to describe BAUMA—WOW !!

It is so big and comprehensive, that it is difficult to properly view, and the best way is to only visit specific stands.

BAUMA is the world's biggest trade fair for construction machinery, equipment and products. It started in 1954, and is held every 3 years in Munich (Germany). The last BAUMA attracted over 1700 exhibitors and 350 000 visitors (from 133 countries), during its one week duration. To gain some idea of the size, it is worth noting that the set-up costs for the exhibitors was reported to be about Dm 200 million (almost R650 000 Million !).



This year BAUMA has moved to a new venue—the newly-opened Munich Trade Fair Centre—that was the old Airport. This year's BAUMA was held between the 30th March to the 5th April 1998, and consisted of 430 000m² of exhibition space (of which 140 000m² was enclosed in 12 massive halls).

The venue was also the location of 4 International symposia:

- ▶ 5th International Symposium on Tunnel Construction
- ▶ 4th International Symposium on Micro-tunnel Construction
- ▶ 3rd International Symposium on Roads and Road Construction
- ▶ 15th International Symposium on Automation and Robotics in Construction

To keep the visitors to those actually interested and involved in construction (and try to make some money probably) admission is Dm 32/day (about R100).

MBT had a large outside stand with a double storey portable office erected on the site. The focus of the exhibits was the New Logica wet shotcrete boom and nozzle that can automatically spray a tunnel to a desired thickness (and then cross-check that the thickness has been achieved). This is a significant advance in shotcrete application technology—especially for major construction excavations.

During my fairly brief visits around the Fair, I was only able to spot one purely South African breed exhibitor,

and that was Bell Equipment, who had a relatively large indoor stand with some heavy equipment on display. I hope that they did well, and that at the next BAUMA more South African exhibitors will be displaying their wares.

On the Thursday, at the close of the Fair, in the early evening, the rail line serving BAUMA failed, leaving tens of thousands of people potentially stranded. The German authorities, however, used their usual magic and managed to produce dozens of buses, and hardly inconvenienced people !!!

BAUMA was, and will be, great and more South Africans should visit and exhibit at the next one (in the new millennium). ♦

* Issued by: Dr A.J.S. Spearing, Senior Manager, Underground Construction Group, MBT International



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The SAIMM is looking for a suitable person to fill the position of editor for a volume of some ten books on current South African Mining Practices. It is envisaged that such a person will be well acquainted with the mining methods in use in South Africa, (perhaps a retired mine manager). A wealth of information is already available to start the books. The SAIMM will support the editor in finding other suitable persons to fill in unknown areas.

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