MOAB KHOTSONG MINE, PART 2

A Mining Engineer's Perspective on the Application of Steel Fiber-Reinforced Wetcrete as a Support Medium in an Ultra Deep Level Mine

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Editor's Note: This is the second part of a two-part article. The first part can be found in the Fiber-Reinforced Shotcrete issue of Shotcrete Magazine *from May 2000.*

4.0 QUALITY CONTROL AND MAINTENANCE

Having discussed the basics for the successful application of SFR wetcrete, the issue of its quality maintenance needs to be addressed. There are a number of critical indicators that the placed product has to meet. They are the required:

- Thickness
- Fiber content
- Mix compressive strength
- In-situ compressive strength
- Bonding to rock face
- Density

From experience, the measuring and analysis of the above can be subdivided into two distinct phases: preliminary quality control and continuous quality control.

4.1 PRELIMINARY QUALITY CONTROL AND TESTING

The main objective of preliminary quality control is to test the initial mix design against the designed specification. The focus of the testing is to determine the energy absorption characteristics of the mix design along with its compressive strength. The method of taking the samples and the testing of such is described below.

Energy Absorption

The purpose of this test is to determine, as closely as possible, the actual placed SFR wetcrete's energy absorption characteristics.

i) Three trays are placed against the sidewall of the excavation to be sprayed. At a point during the spraying process, the plates are sprayed fully with the SFR wetcrete product. These trays are then left in-situ for a period of 28 days to cure in the same environment where they were sprayed. After 28 days, they all must be carefully transported to the surface. Upon arrival at the surface, the SFR wetcrete plates are removed from the trays, trimmed and sent for the EFNARC plate testing.

ii) From these test results, it is then possible to determine the energy absorption characteristics of the SFR wetcrete. Should there be a high degree of difference between the actual compared to the design specification, a re-examination of the mix design may be required. Usually, the variance lies with the fiber content, as this directly relates to the energy absorption characteristics.

Compressive Strength

The purpose of this test is to ensure that a quality test can be done on the SFR wetcrete's compressive strength.

i) When spraying the three trays discussed above, it will also be necessary at the same time to spray a fourth tray from the same batch. This is necessary so that the compressive strength results can be directly related to the energy absorption results. This tray, once sprayed, is also allowed to cure in-situ for 28 days. At the end of this period, the tray must be drilled for six cores, all 100 mm long and 50 mm in diameter (4 in. long and 2 in. in diameter). Once the core is drilled, it must be carefully transported to the surface and dispatched to the lab.

ii) These cores will then undergo a compressive strength load test and from there, an average compressive strength can be determined.

Both of the above tests only need to be carried out under the following circumstances:

- Annually as a check.
- Should environmental conditions drastically change (higher air velocities).
- Should any changes to the mix be required.
- If any changes in equipment used.
- If any changes in the method of application.
- If any changes in the operating crew.

It should also be noted that when the trays outlined above are being sprayed, all of the following continuous quality control tests must also be carried out. By doing so, it is then that much easier to relate the continuous quality control test results to the key results of energy absorption and compressive strength obtained in the above testing.

4.2 CONTINUOUS QUALITY CONTROL AND TESTING

This section deals with tests used on a daily basis to ensure that the SFR wetcrete applied is maintained against the design specifications. The type of test and frequency of such will vary from site to site and will very much depend on production rates.

Penetration Needle Test

This test, as the name suggests, consists of a needle that is pushed by the operator into the SFR wetcrete sprayed onto the rock excavation. A reading can then be obtained that relates back to its early compressive strength. The test must be done within one hour of the SFR wetcrete being sprayed and for every batch sprayed. If it fails to meet design requirements, spraying must be stopped so that the problem can be investigated and immediately rectified.

Thickness Test

By using indicators (plastic pointers attached to the excavation wall), the operator can control the thickness sprayed to ensure that the design specification is met. On a weekly basis, a quality controller will visit the spray site underground and will, on a random basis, drill holes into the placed SFR wetcrete to check that the applied thickness is to specification.

24-Hour Cube Test

At the surface batch plant, cubes are poured for each spray period (Day). They are allowed to cure for 24 hours and then subjected to a compressive strength test. The result will indicate whether the SFR wetcrete is on the 28-day strength curve. If not, then the quality of the mix must be investigated and corrective action taken.

7-Day Cube Test

Also at the surface batch plant, after every seventh set of 24-hour cubes, three 7-day cubes are poured. These cubes are allowed to cure in a water bath for a period of 7 days. After this period has elapsed, they are then subjected to a compressive strength test to confirm whether the SFR wetcrete mix is on the 28-day strength curve.

Bonding and Core Test

On a basis that is very much site-dependent, a bonding and core test must be conducted. This has been defined on the Moab Khotsong Project as being at 10 m intervals. The excavation sidewall is built up during normal spraying operations to a thickness of 120 mm (4.7 in.) for an area of 1.0 m^2 (10.7 ft^2).

Figure 1. Surface batch plant

A core drill is then mounted on the sidewall in this position and three 50 mm (2 in.) cores are drilled to a depth of 100 mm (4 in.). Note that the cores must be left in position. A dolly is then bonded to each of the cores, and in turn, they are attached to a puller and put under tensile load until they break free from the rock face. The readings obtained indicate the bond strength of the in-situ SFR wetcrete.

The same three cores are then also used to determine the in-situ density and finally are dispatched to the surface for testing to determine the in-situ compressive strength.

Figure 2. Mixing plant

Fiber Content Test

The purpose of this test is to determine fiber content of the placed SFR wetcrete. On a daily visit to the spray site, the quality controller must take a grab sample of the wet SFR wetcrete and, using a measuring vessel, scales, and sieve, determine the fiber content of the sprayed SFR wetcrete.

5.0 EXPERIENCE TO DATE AND LESSONS LEARNED

There are a number of experiences that should be brought to the attention of the mining engineer planning the use of SFR wetcrete as a support medium.

5.1 MIX DESIGN

i) The main problem with the mix design encountered to date has been pipe blockages due to the balling of the steel fibers. Originally, a bonded fiber (glued together with a soft glue) was used, but it was found that the fiber would not break apart during mixing and hence, cause pipe blockages. This problem was resolved by the introduction of a loose fiber.

ii) Another minor problem was the dosing rates of the SFR wetcrete activator, which is applied at the spray nozzle. In the early days, due to inexperience, the crew did not identify problems with the dosing pump and rates. The end result was a high degree of rebound. This was rectified with further on-the-job training.

5.2 APPLICATION SYSTEM

There were a number of problems encountered with the system.

i) The wetcrete pump is actually a very sophisticated piece of equipment. As such, it needs a high degree of attention and maintenance. The electronics of the system are also very sensitive to dust and high humidity levels encountered underground. These conditions eventually resulted in damage to the PLC units that then had to be replaced. Eventually, the box containing the electronics was modified and is now pressurized to prevent the inflow of dust and moisture during operation.

ii) Due to the early completion of work, mothballing of the pump was required from time to time. Due to the limited access to surface, the equipment usually had to be mothballed underground. This also led to the deterioration of the PLC units. In the future, due to a modification to the electronics box, it will be possible to unplug the box and bring it to the surface for safe storage.

5.3 APPLICATION

i) The main problem encountered with the application was the handling of the rebound. The first step was to identify the cause of the excessive rebound. Eventually, it was found that there was a problem with the activator dosing as discussed above. A secondary problem was the disposal of the rebound. A method of adding molasses with the rebound in paddocks (which prevents the cement from binding) was implemented. This meant that the rebound could then be loaded and tipped into a conventional orepass system. This was previously not possible due to potential blockages.

ii) Sludge disposal has also been of concern. The sludge is generated from the lining of the column from the surface prior to pumping the SFR wetcrete and from cleaning the column/system (flushing). This was treated in the same manner as the rebound. The sludge has also been minimized by preparing a site for spraying, and setting up the crew so that they can spray for longer periods. This reduces the number of times the columns have to be flushed. The crew has sprayed continually for up to 16 hours.

iii) Finally, spraying over mesh that had been previously installed during sinking operations proved to be a problem. This problem was actually twofold. First, it proved very difficult to spray through the mesh to fill the cavities behind it, and second, the vibration induced in the mesh would cause debonding. This was resolved by stripping off the old mesh that was previously installed. It is also suggested that to achieve a good, cost-effective finish, all loose chain, ends of rope anchors and protruding material be trimmed off before commencing the spraying operation.

6.0 RESULTS TO DATE

6.1 SUPPORT METHOD

Through experience, a number of methods have been developed that have led to the successful integration of SFR wetcrete into normal support systems.

Figure 3. Pump Receiving hopper and delivery pipe.

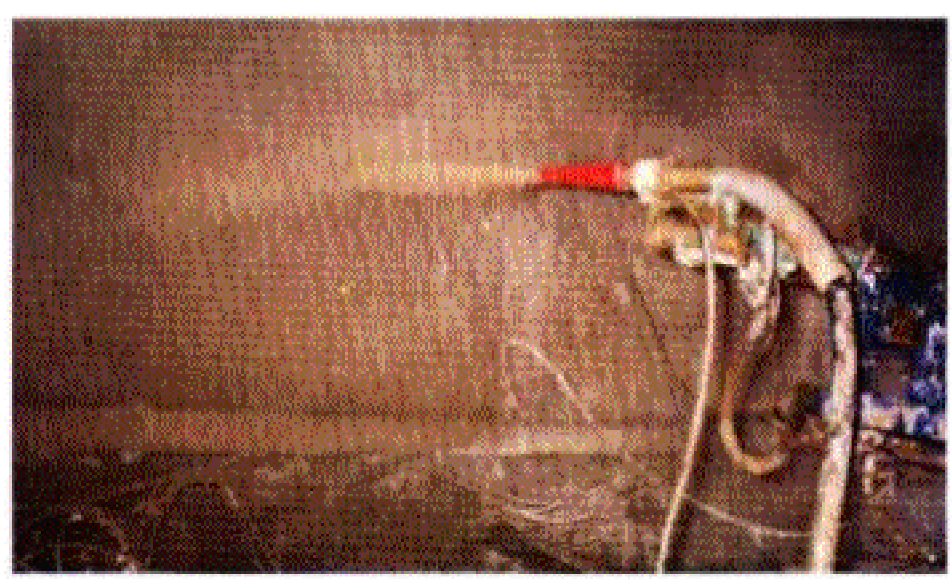

Figure 4. Robojet sprayer.

Pre-Wetcrete

If the ground conditions dictate, the ground will first be consolidated with the application of a 50 to 100 mm (2 to 4 in.) layer of SFR wetcrete, ensuring all cavities are filled. Once this is completed, the area is drilled and supported as required. This is then followed by a final layer of SFR wetcrete that will cover all of the above and build up the SFR wetcrete to its specified thickness.

Table 3

	cubic meters (m^3)
Sent Underground	4083
Wasted	231
Sprayed	3852
Rebound 7%	2520
Installed	360
% on Rock Face	88%
Area Sprayed (100 mm)^3	**36,000 m^2**

Table 4

At 100 mm (4 in.) thick	**Covered m^2 per m^3 of concrete**
Average	8.95
Best	10.45
Industry Norm	9.52
Theoretical Norm	12

Another useful tip is to trim the anchors, etc., to the same length as the required SFR wetcrete thickness so that they can act as thickness gauges.

Post-Wetcrete

If there is proper consolidation of the excavation required, such as removing mesh, loose rock, etc., prior to the final support being installed, then the remedial work is carried out first and the new support installed to specification.

Upon completion, all of the cavities are spot-filled, and only then is the SFR wetcrete sprayed and built up to the final thickness.

6.2 PRODUCTION

The production to date is shown in Table 3.

6.3 PLACEMENT EFFICIENCIES

The efficiencies obtained to date are shown in Table 4.

The production rates and efficiencies have far exceeded initial expectations and appear to remain consistent.

7.0. CONCLUSION

On examining the content of this article, it will be obvious to the reader that there are a number of key issues that the mining engineer must consider prior to implementing SFR wetcrete as a support medium. The key issues being:

- Determine the support required from the SFR wetcrete (work to be done).
- Define application rates.
- Define size of excavations to be supported.
- Determine method of supply.
- Ensure that the whole system is compatible and matches, such as the manufacture rate of the wetcrete meeting the required application rate.
- Examine the logistics of moving the equipment.
- Determine the method/system of handling rebound.
- Develop sequence of application.
- Determine and develop quality control requirements and system.

In conclusion, the results-to-date are very favorable toward the future use of SFR wetcrete as an effective medium of support, especially in an underground environment were minimal dust generation is a prerequisite. In addition, the system has proved itself particularly effective when the SFR wetcrete is to be applied as an immediate form of support for excavations.

The task that now lays ahead of the Moab Khotsong team is to adapt this technology for use as support in rapidly advancing tunnels, the details of which the author will expand upon in a future article.

The objective of setting down my experiences in this article was primarily to be of assistance to my fellow mining engineers, in terms of the planning and implementation of SFR wetcrete as a mining support system. If this has proven to be the case, then the writing of this paper has more than justified the time and effort it took to complete.

Jon Buckley has been with Anglogold since 1988. His first position was that of Junior Mining Engineer, and over the following years he held various positions within the company. From 1996 to 1999 he was Project Manager of Capital and Sinking operations at Moab Khotsong Mine; responsible amongst others for sinking a sub-shaft system to a depth of 3100 m (10,170 ft) below the surface. He is now a Manager for Anglogold Corporate office on a mining technology integration project.