

# Slope Stabilization in an Open Pit Mine

by Michael Keienburg

**T**he government of the Republic of Botswana and De Beers Centenary AG own the Debswana Diamond Company in equal share. Debswana Diamond Company is the world's leading diamond producer by value and quantity. Debswana has played a significant role in the transformation of Botswana's economy. It is the largest nongovernment employer and earner of foreign exchange in Botswana. Debswana's mining operations have been chiefly responsible for transforming Botswana from an agriculturally-based economy in the 1960s to a country that has

subsequently consistently displayed one of the highest economic growth rates in the world.

The De Beers Botswana Mining Company was formed in 1969. Orapa Mine started production in 1971 whereas Letlhakane Mine started in 1976. In 1973, De Beers geologists discovered the Jwaneng pipe, which would become the richest diamond mine in the world. In 1991, the company changed its name to Debswana Diamond Company (Pty) Ltd. and established its new corporate headquarters at Debswana House in the capital city Gaborone. Damtshaa, the fourth Debswana mine, commenced production in October 2002. The mine is located some 15.5 miles (25 km) east of Orapa, from where it is administered.

Debswana produced a record 31.9 million carats in 2005, almost 1 million carats more than the previous year's production. The company operates its own laboratory for sample treatment, mineral sorting, and classification, as well as petrologic studies including petrography and geochemistry. Debot operates an extensive database spanning over 40 years of prospecting activities and employs 23 earth scientists and some 150 permanent staff. This broad experience base allows the undertaking of all prospecting activities from grass roots exploration to advanced-stage evaluation and feasibility studies using the most advanced techniques available.

When we talk about open cast mining in general, we picture big openings, heavy equipment, and a rough terrain. The various problems of logistics, as well as target achievements, are mainly a concern of the management and teams working in this rough environment. Here at Letlhakane of Debswana, the geology is shown in a predictable way with a section of mudstone. This type of geology is very sensitive to the environmental conditions (weathering) and it limits the mine to excavate at shallow slopes. Mudstone rock can be mined safely at a slope of 26 to 28 degrees. Debswana has researched the natural behavior and physical strength of the mudstone on slopes since 2001.

The mudstone is located below the sandstone and a weathering of the mudstone would cause a chain reaction collapse. The mudstone would weather and undercut the competent sandstone benches resulting in potential fatal bench failures.



*Process Plant of Debswana*



*Excavation activity*

The finding (natural slope 26 to 28 degrees) was not acceptable, as it would tremendously lower the amount of ore for mining, as well as the life of mining. The increase to a 40-degree natural slope was the target to be achieved but would require stabilization using shotcrete.

The mudstone has the mechanical strength to provide enough support for the previous geology (sandstone and basalt) as long the mudstone can be kept under ideal conditions. This requires a minimum layer of 2.4 in. (60 mm) of shotcrete. Trials with Sika/Putzmeister equipment during the first quarter of 2006 are being conducted to optimize the shotcrete application.

Due to the professional research of Debswana personnel, the base for a custom-made solution was provided. Various mixtures based on different slope stabilization systems were evaluated under real conditions to find the most effective way to achieve the target.

The shotcrete method crystallized at the very end as the most efficient method of sealing the exposed mudstone faces. The possibility of reinforcing the shotcrete with fibers to change the mechanical characteristics is an option that is being pursued. A surface of 413,813 yd<sup>2</sup> (346,000 m<sup>2</sup>) has to be covered with shotcrete up to the year 2011. The horizontal beams will not require any additional mechanical support because the support provided by the shotcrete will be sufficient.

Debswana had to consider not only weathering of the mudstone, but also the mechanical strains from geological conditions, as well as operational issues (fly rock), logistics, operation time for shotcrete application, and financial issues. These were all factors with high influence that were taken into consideration in selecting shotcrete. Debswana involved various expert companies as soon the trials reached a stage of overlapping expertise.

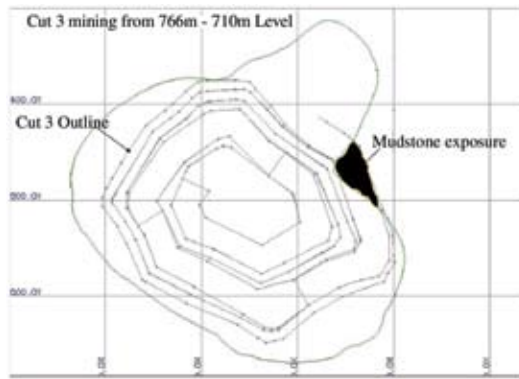
The target was clear as it required protecting the mudstone:

- a. Prevent water ingress into the mudstone;
- b. Prevent the action of oxygen on the exposed faces (slaking); and
- c. Preserve the inherent moisture in the mudstone.

The system needed to be able to maintain integrity and stability of the upper benches and was required to be applied immediately after blasting operations.

There were challenging site and logistics conditions for shotcrete application:

- Maximum bench height of 46 ft (14 m);
- Maximum slope 85 degrees;
- Spraying rate of 39 yd<sup>3</sup>/h (30 m<sup>3</sup>/h);
- Availability 83%;
- Utilization 90%;
- 16 hours of operation; and
- 12 hours of overall utilization time.



*Topographic view of mudstone area*



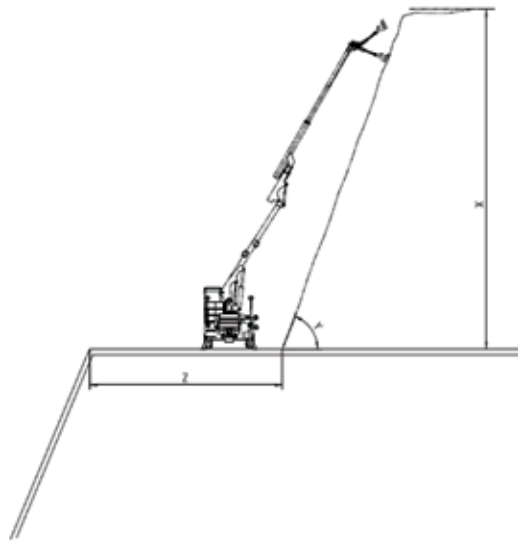
*First shotcrete trials*



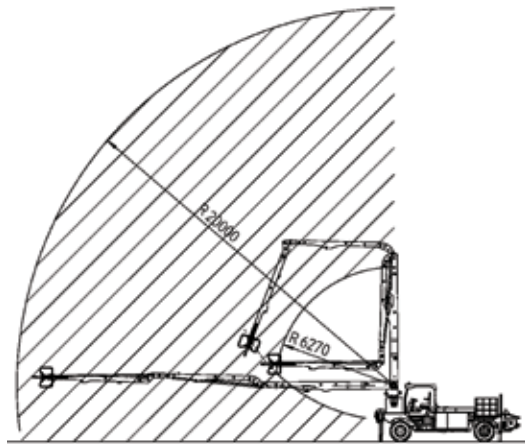
*Evaluation of shotcrete application*



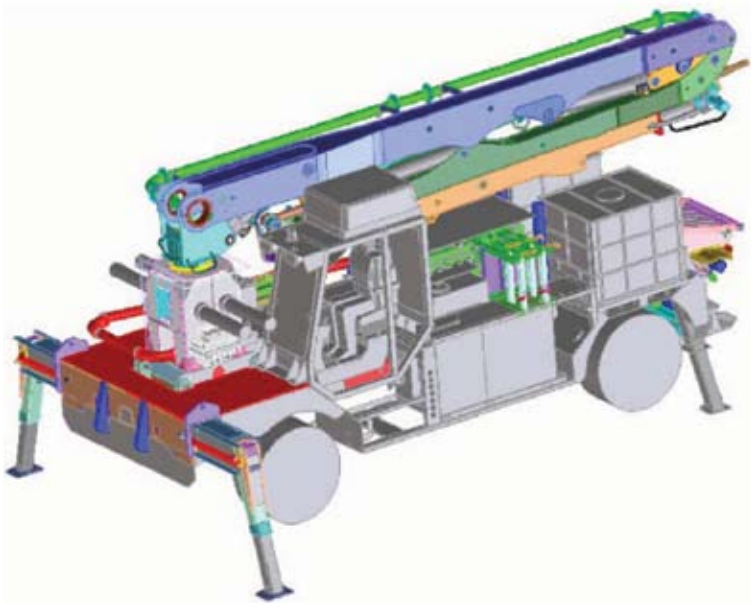
*Client visit of Sika Schweiz AG Machine Factory in Widen*



*Sketch 1: Illustration of required performance toward geometry of working area*



*Sketch 2: Solution for required performance toward geometry of working area*



*Schematic view of Sika PM-500PCD*

These challenges were met by:

- The innovative boom design of Putzmeister with a length of 66 ft (20 m) that enhanced the work area from a single set-up substantially;
- No telescopic movement of the boom;
- Simplified work procedure for slope spraying;
- Enhanced outrigger system;
- Acclimatized operator cabin; and
- Easy accessibility of working area as unit is self contained.

The expert teams of Debswana and the Sika Schweiz AG Tunneling and Mining Department came up with a solution to achieve an acceptable open cast mine. The Sika PM-500PCD was designed to work autonomously. No external power source is required for operation. This is a clear benefit to the mine as high mobility is required as well as rapid operation and deployment. Various slope heights and angles can be covered with shotcrete without changing mounted equipment or having various other systems purchased to work on the same job.

The installation of two 264 gal. (1000 L) tanks on top of the carrier allows for carrying chemicals for the shotcrete process and water for the after treatment of the shotcrete (curing). A control system mounted into the side section of the carrier facilitates operation of the unit. Various mixtures can be programmed and called for by the operator. The intelligent control system supports the logistic efforts and supplies all information required to perform the job efficiently.

Debswana has established its own concrete plant, which uses local materials to produce the shotcrete. Provision of sufficient concrete mixing trucks was another step to finalize the supply and production chain for the shotcrete application.

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