Lining Raise-Bore Shafts

By Kristian Loevlie

When raise boring is used, a circular excavation is produced either between two existing levels in an underground mine or between the surface and an existing level in a mine. In raise boring, a pilot hole is drilled down to the lower level, the drill bit is removed and replaced by a reamer head having a diameter of the same dimension as the desired excavation, and this head is rotated and pulled back up toward the surface.

Oftentimes, the ground consists of various geological layers—some are very unstable and need to be controlled as soon as possible; otherwise, the hole may collapse. Because workers are not allowed in unsupported ground, the conventional way to line a raise is to use steel cans or forms from top and down, in stages, and backfilled with concrete. This is a slow and lengthy process. Initial support is always an issue, which then can decide the stability or collapse of a shaft.

Introduction of robots using dry-mix shotcrete were a huge improvement and saved many shafts from collapse. It still took weeks or months to finish, leaving the ground open and exposed to the elements. Wet-mix shotcrete was not considered due to logistical problems, plugging hoses after a certain vertical distance, the weight of the hoses full of concrete, the shotcrete going into a "free fall," and so on.

Facts

- Pneumatically operated centrifugal lining works in 2 to 12 ft (0.6 to 3.6 m) diameter shafts and will place up to 8 yd^3 (6 m^3) per hour of shotcreting.
- For shafts 10 to 20 ft (3 to 6 m) in diameter, STI uses a continuous 2 x 2 in. (50 x 50 mm) nozzle robot. The two nozzles keep the robot centered, minimizing the violent bouncing that using only one nozzle would create.
- The two-nozzle robot will spray up to 14 yd^3/h (11 m^3/h). The shotcrete mixture is pumped through all the hoses on the surface before being lowered down, connected to the cable every 50 ft (15 m) to disperse the weight of each concrete hose.
- The lining of 1000 ft (300 m) shafts is easily achieved and we are considering lining much deeper shafts using the double nozzle system.

When it comes to sprayed concrete lining, there is conventional dry-mix shotcrete (water added at the nozzle) or wet-mix shotcrete (air added at the nozzle). Both technologies have long been used for lining horizontal pipes, tunnels, culverts, and vertical shafts.

In a whitepaper by Morgan et al. (2010), the authors explain that these systems have generally worked well and provide high-quality lining. They are not without their challenges, however, including maintenance of the robotic rig and the need to regularly clean the shotcrete nozzle. Shotcrete Technologies, Inc. (STI) developed another option—a centrifugal-sprayed concrete spinner head system that they have used in horizontal structures since about 2005. In 2009, they deployed the first use of this technology in North America to line a 11 ft (3.5 m) diameter, 1000 ft (300 m) deep raise-bore shaft at the New Afton copper-gold mine near Kamloops, BC, Canada (owned by mining company New Gold).

At the New Gold Project, STI demonstrated that centrifugally placed wet shotcrete can be used to structurally line 1000 ft (300 m) in substantially less time than with robotically placed dry-mix shotcrete. The timeframe was 6 days versus 6 weeks in this particular case.

For the wet-mix centrifugal sprayed concrete, instead of adding water at the nozzle as in dry-mix shotcrete, or air at the nozzle as in wet-mix shotcrete, the concrete mixture is pumped to a spinning head, which spins at 4000 to 5000 rpm. The concrete is then centrifugally sprayed onto the receiving surface at high velocity.

In 1998, Pan American Silver acquired the La Colorada underground silver mine in Zacatecas, Mexico, in the Sierra Madre mountain range. An expansion of the mine, launched in 2014, will increase the mine's capacity from 1250 tons (1130 tonnes) per day to 1800 tons (1630 tonnes) per day by 2018.

Work is expected to be complete by 2017, and involves the construction of a new 2000 ft (600 m) deep extraction shaft between two of the mine's main zones, with a capacity for hoisting ore and waste of 2300 tons (2100 tonnes) per day, as well as serving as the main access to working areas for mine personnel and additional underground development to extend the operations for deeper levels.

Pan American Silver was raise boring the 2000 ft (600 m) deep by 20 ft (6 m) interior diameter shaft in Zacatecas last fall. Construction of the new shaft advanced smoothly through good ground conditions that allowed construction crews to compete the 1030 ft (312 m) of the raise bore, according to Michael Steinmann, Pan American Silver's President.

LINING A SHAFT IN ONE DAY

The upper 700 ft (210 m) was in questionable ground, so it was decided to raise a smaller 10 ft (3 m) diameter bore to shotcrete the shaft and then excavate from the top down.

The day after the bore machine was removed, crews lowered a camera down and marked where the shotcrete was needed—a total of 240 ft (70 m) in various areas.

"At 11 a.m. we started lining a flash coat, top to bottom," says Kristian Loevlie, President, Shotcrete Technologies, Inc. "We then lined 3 in. (75 mm) of shotcrete where needed and by 6 p.m. the same day, we had completed the shaft lining."

A total of 38 yd^3 (29 m^3) was in place. The company made its shaft lining concrete mixture on-site using local materials and the on-site batch plant. "We used 900 ft (270 m) of hose to keep everything flowing smoothly," Loevlie adds.

There was no noticeable rebound and this structural shotcrete reached 3000 psi (20 MPa) in 24 hours and 7000 psi (50 MPa) in 14 days.

PAN AMERICAN SILVER

Fig. 1: Hoses before lining

Fig. 2: Lowering the egg into shaft

References

Morgan, D.R.; Loevlie, K.; Kwong, N.; and Chan, A., 2010, "Centrifugal Sprayed Concrete for Lining Horizontal Pipes, Culverts, and Vertical Shafts," 3rd International Conference on Engineering Developments in Shotcrete, New Zealand, Mar. 15-17, 7 pp.

Fig. 3: Shaft lining with the spider

Fig. 4: Crane over the shaft

*Norwegian-born **Kristian Loevlie**, Cofounder and Owner of Shotcrete Technologies, Inc. (STI), is one of the world's leading experts in wet-mix shotcreting. His technical expertise, including specifications, mixture designs, logistics, equipment and system design, and training has provided STI a firm foundation in the shotcrete world with the cutting edge of new technology and techniques.*