Rising to the challenge

Raise boring, a widely used technique in the mining and civil sectors, has come a long way over the years. Today, it is often the preferred means of excavating openings in underground projects

In underground mines raise boring is used in the construction of major capital infrastructure such as ventilation shafts, material passes and manways. It is also, at times, chosen for mine production, particularly in block-cave mines for slot raises.

On the civil side, the method is used for road and rail tunnel ventilation; hydro penstocks and surge chambers; redirection and retrieval of hydro water, pressurised gas and nuclear waste storage; stormwater storage and drainage; as well as access ways for pipes, hoses and cables.

A generation ago, to construct a raise, hazardous, manual shaft processes meant miners had to work under a newly blasted rock face in the shaft that was being constructed – and it could only be done by the most experienced workers. However, when James Robbins built the prototype Robbins 41R raise drill in 1962, it was the beginning of a new era.

"Boring of raises had attractive features over traditional methods. It was faster, cleaner and, above all, allowed for remote access and operation, removing the risks associated with entering long raises for drill-and-blast purposes, such as those associated with rock falls, working at heights and ventilation," explains Pybar Mining Services' chief operating officer, Brendan Rouse. "Raise drills can now bore holes 1,200m long and up to 8m in diameter."

Nonetheless, TRB-Raise Borers CEO Jarko Salo notes: "Despite its obvious advantages, raise boring as a shaft-construction method is not as universally accepted as one might suppose. Dangerous, manual shaft-construction methods are still all too frequently employed." ▶

Atlas Copco's Easer L raise-boring machine

A mid-sized RHINO raise borer at a drill site ►

In raise boring the risk of rock falls and the handling of explosives is eliminated as the operation is mechanised. The final product of the method is a raise excavated with minimal disturbances to surrounding rock.

"This is advantageous in ore and waste passes as the walls are less likely to degrade due to pre-fracturing. Overbreak is non-existent, reducing the costly need to support or rehabilitate excavations," says Yves Benoit, senior engineer and estimator for Redpath Raiseboring.

How does it work?

Raiseboring is a versatile method for vertical or near-vertical excavation in underground mines and civil projects. It makes use of mechanical excavation to bore through rock rather than conventional drill and blast.

There are a number of different rigs on the market with specific hole-size capabilities and other features that each suit a variety of applications.

Conventional raise boring is used where there is access to the top and bottom of the hole. The rig is set up on top of the hole and a small pilot bit and rods are used to drill through to the opening at the bottom of the hole. The pilot drill bit is removed and a larger reaming head attached. The rig puts upwards thrust onto the rods and the reamer cuts through the rock from the bottom to the top of the hole, where it is removed.

Boxhole boring is used to excavate raises where there is limited or no access to the upper level. Here, the machine is set up at the lower level and a full-diameter raise is bored upward. While boring upward, stabilisers are periodically added to the drill string to reduce oscillation and bending stresses. The cuttings are carried by gravity down the hole and are deflected away from the machine. Boxhole boring can be completed with or without a pre-drilled pilot hole.

Blind shaft boring is used where there is access to the upper level of the proposed raise, but limited or no access to the lower level. With this method, the raise is excavated from the upper level downward using a down-reaming system connected by a drill string to the machine above. Weights are added to the reamer mandrel. Stabilisers are located above and below the weight stack to ensure vertical boring. A reverse-circulation system, or a vacuum system, is typically used to remove the cuttings out of the shaft.

Down reaming begins by drilling a conventional pilot hole, and then enlarging it to the final raise diameter by reaming from the upper level to the lower level.

"The circular, smooth-walled finish of raise-bored holes is most efficient for ventilation as it allows for the unhindered movement of air. When compared with equivalent rough-walled raises, raise-bored holes require approximately 20% less area to pass the same volume of air, resulting in savings in both capital and operating costs."

One of the requirements for using the technique, however, is boring through competent ground. "Where ground is unstable or fractured," says Benoit, "conventional methods, such as drill and blast, are preferred."

CONTINUED EVOLUTION

Today, automation and smart technologies are increasingly being applied to raise drilling, with operators frequently asking for functions to be automated to help them move away from unsafe operations. At mines where effective hours at the machine are limited, automation can also allow for extra productivity and, in turn, a lower cost-per-unit excavated.

"We also have customers asking for fully autonomous machines. This is an interesting area where we already have the technology to build them, but it's not economically effective to do so yet," comments Johnny Lyly, global product manager for raise boring at Atlas Copco.

Redpath says it also has some Redbores in the field that are automation-ready.

Rouse explains: "While boring, large stresses are built up in the drill string and variable ground conditions introduce the risk of rod-string damage or catastrophic failure. New control systems ensure that the operator can select the optimal running parameters to get the most out of the raise drill, both in terms of performance and economy.

"Functions such as automatic shutdown and anti-jamming make it possible to continue drilling during periods when the machine ►

Pybar's RBR-600VF raise borer at the Didipio gold mine in the Philippines

might otherwise be unattended. Computerised systems are now a common option on new raise borers, as well as retrofitting to older machines."

Moreover, mobility of raise-boring machines and support equipment is increasingly a factor to consider in the design of machines, particularly for use in underground mining where transport and establishment of large items of equipment can be time-consuming and disruptive to continuous normal operations. Machines that are 'self-mobile' are increasingly being used, supported by purpose-designed support vehicles to minimise disruption.

"Our design over the last few years has been focusing on mobility; for example, our Easer machine has greatly improved the mobilisation of the raise-boring setup. Before, there was always a need to install the derrick on a concrete pad or use a base plate with jacks to level the derrick and secure it to the ground. Our Easer has removed those things and setup only takes a fraction of the time needed before," says Lyly.

The Easer is the latest raise-boring machine in Atlas Copco's range and is intended for slot raises in block caving and certain types of sublevel mining.

"A rig that can drill a short raise for the rock to expand against when blasting, without the need for a concrete pad to tie the derrick against, is needed in these applications. Here, our Easer fits perfectly as it drills 750mm-diameter holes up to 60m long, and the setup procedure doesn't require any site preparations at all," continues Lyly.

According to Benoit, the most interesting and exciting developments in the Redbore line of raise drills involve the introduction of variable frequency drives (VFD) and programmable logic controllers (PLC).

"In the past, all raise drills were driven by hydraulic or DC drive systems, which allowed for little control over rotational speed and torque," he explains.

"With Redpath's introduction of VFDs drives to the raise-boring industry, it is now possible to exercise absolute control over rpm and torque. Where a conventional machine might have been locked in at 3rpm at full torque, the same machine may now operate at any speed, and at any torque. This grants the operator unprecedented control over the drilling and reaming process.

"Most importantly for mine owners, the electric-powered VFDs are highly efficient, requiring less than 50% that of equivalent hydraulic drives."

"Redpath's Redbore line of raise drills is controlled via advanced PLC systems. The ability to program logic within raise drills has been of tremendous advantage to Redpath, as it adds features such as self-diagnostics through sensor arrays, and adds safety features such as proximity e-stop, performance monitoring, remote troubleshooting, braking and automation," he adds.

These elements are on display in the Redbore 90 and Redbore 100 raise drill models aimed at large-diameter raises.

A good raise-boring operation also includes safe and effective rod-handling practices. "Apart from the time taken for the raise borer's transport, drill-string handling and rod change are the greatest non-productive aspects of raise boring, and have also traditionally been the most hazardous," warns Salo.

"Modern remote-controlled rod-handling operations provide higher productivity, while reducing safety concerns."

As demand shifts away from traditional drill-and-blast excavation methods, the raise-boring industry as a whole is experiencing higher demand than ever before.

"In the past, large-diameter

"As demand shifts away from traditional drill-and-blast excavation methods, the raise-boring industry is experiencing higher demand than ever before"

Redpath raise drills include the latest technology in touch screens, on-board computers and data-collection software. Pictured are the Redbore 90 and Redbore 40S

excavations were completed exclusively via drill-and-blast methods," says Benoit.

"Technological advances in the raise-boring industry have led to size offerings in the 8m+ diameter range. When warranted by geological conditions, raise boring has been favoured by clients seeking to complete shafts, material-handling raises and large-diameter ventilation raises. It's worth also noting that advancements in directional drilling technology have made raise boring a viable method for conveyance shafts – since this technology allows pilot holes to be drilled with near-perfect verticality over thousands of metres."

CASE STUDY

Raise-bored slot raises

According to TRB-Raise Borers' CEO Jarko Salo, during mine production, raise boring is seldom used.

"Despite its many potential benefits, its lack of mobility makes raise boring an unattractive alternative for production drilling," he explains.

Slot-raise drilling is the most suitable production drilling application for raise boring. Slot raises refer to relief holes within a stope, intended to provide void space for blasting, thereby allowing 'expansion' of the blasted rock and improving fragmentation.

Nowadays, there are several methods used in mines to produce these slot raises: long-hole rigs, manual drilling methods and even conventional raise boring.

To increase production in an underground operation, any slot-raise rig must reduce the production complexities and simplify the mining process. While the potential is certainly there, the challenge is to make raise boring an appealing alternative.

"To increase production in an underground operation, any slot-raise rig must reduce the production complexities and simplify the mining process"

"To utilise the benefits of conventional raise boring while also addressing the drawbacks, it soon became obvious that an entirely new type of highly mobile, self-contained raise borer for underground production drilling had to be built," notes Salo.

This new unit had to include several capabilities: rapid machine setup, to effectively drill holes that were suitable for production and to be suitable for swift dismantling/relocation.

Such a unit would also not require a concrete pad, no additional rock works, nor any special utilities or provisions other than the ones already established for the equipment operating in the same drifts.

Agnico Eagle's Kittilä gold mine in Finland commissioned such a unit. The mine uses the sub-level stoping mining method. The average stope height is 25m but can be as high as 40m.

Each stope has two accesses: the overcut and the undercut. The original long-hole open stoping method required 21 drill holes for opening a drop raise in each stope, using the same conventional long-hole rigs as used for drilling blastholes.

The drop raises required five to six workdays to construct, including all the drilling, blasting and hauling stages, and necessitated the use of two drill rigs and several members of crew. Using long-hole drilling for the drop raises not only doubled the number of holes required but also made it necessary to blast the drop raise in five-metre breaks, which requires a lot of space as well as multiple work stages.

There was also a safety consideration involved in this process. Due to the challenging rock conditions presented by the sulphide-rich mineralisation, the method also required re-drilling after each blast in order to open closed holes.

Re-drilling holes after blasting is inherently risky due to the potential for encountering 'live' detonators that could trigger an explosion during re-drilling.

The mine replaced these drop raises with raise-bored slot raises. Now, with a raise borer, all work stages and complications could be replaced with a single machine, a single operator and a single work-order.

The new method also eliminates the safety concerns associated with explosives because raise-boring slot holes make it unnecessary to blast at all before the actual production blasts.

The solution was developed by TRB-Raise Borers when the RHINO 100 raise borer took over in July 2014, and the conventional long-hole top-hammer drill rigs were assigned to other tasks.

The rig itself is an articulated, highly mobile unit capable of carrying all the equipment necessary to drill a 30m slot raise. This means the operation and setup follows the same principles as with any mining jumbo or long-hole rig operation.

Hydraulic jacks and stingers are used to establish the drilling position, with actual drilling starting immediately afterwards. Indeed, the first piece of drill string is already attached to the gearbox. This design integrates dust suppression and a muck chute to create a dust-free drill site and take the cuttings away from the rig.

Salo explains that to achieve the best raise-boring performance, the rig and the tools are designed to work as one integral unit.

The raise-boring tools are manufactured by Sandvik. The combination of an 11in (279mm) pilot bit and two raise-boring cutters allows the raise to be completed in a single pass.

The drilling concept utilises

The RHINO 100 provides a new method for drilling slot raises in underground mines

standard raise-boring tools to achieve maximum cost-efficiency. The tools, including the cemented carbide buttons, are optimised for high-rate penetration and long service life. The cutters are installed on a reaming head customised for this specific application.

The reaming head is made of forged and accurately machined high-alloy tool steel, allowing for change of distance between the pilot bit and the reaming head. As a part of its quick setup characteristics, rod handling on the RHINO 100 is optimised by including a crane and a manipulator, controlled either with a wireless remote controller or from the operating cabin.

The 21 holes required for opening a drop raise in each stope will now be replaced by larger raise-bored slot holes using the RHINO 100.

The new process at Kittilä started from scratch. None of the operators had any previous experience with raise boring. Starting from its commissioning in July 2014, only one stope and 105 drilled metres were achieved in the first month – very much at the bottom of the learning curve. From there on, the pace improved up to eight stopes and 410.3m/month in October 2014, three months after commissioning. The output over the entire year totalled 64 stopes, 11 mine infrastructure shafts and 2,993 drilled metres.

"We now need only two blasts, even for those 40m stopes, and opening up the drop raises in five-metre breaks has been eliminated altogether," underground planning engineer Elen Toodu, points out.

"Before RHINO, we couldn't imagine blasting 145 stopes a year. The stope cycle time has become significantly shorter.

"This has also freed up the long-hole rigs for drilling the actual blastholes instead of opening up drop raises. This job previously required 30% of our long-hole drilling capacity without adding basically anything to the tonnage."

The calculations originally showed that many stopes would only need one slot hole, but the decision fell on two holes per stope as a standard and three in difficult stopes to maximise the security of the process – an easy decision to make especially as it does not compromise the productivity.

Drilling both slot holes with the RHINO 100 takes two days instead of the five to six required for the drop raises by traditional long-hole drilling.

"In conclusion, the success in this new process has offered some significant benefits for the mining operations at Kittilä. The quick and easy solution for drilling slot raises can maximise output and minimise risks, without compromising productivity," says Salo.

"Clearly, raise boring can be a productive mining method. The basic fundamentals provide a safe and simple process, which is very fitting to underground conditions."

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