Raise boring slots: a modern mining technique

Raise boring has commonly been employed at different stages of mine construction for decades, most frequently as a means of drilling shafts, raises and ore chutes – but seldom (despite the endless possibilities) as a production method…until now, writes *Jarko Salo*, the managing director of TRB-Raise Borers.

Raise boring was originally developed to replace hazardous manual shaft construction where miners had to work under newly blasted rock. Despite its obvious advantages, raise boring as a shaft construction method is not as universally accepted as one might suppose. In raise boring the risk of rock falls or the handling of explosives is eliminated as the rock excavation process is mechanised.

Raise boring is not only a safer method, but it is also a much more productive one: shaft construction is quicker; and the outcome is a perfectly round profiled hole with smooth walls. Indeed, such raise bored shafts provide an ideal solution for ventilation shafts. The smooth walls promote laminar air flow in the shaft, therefore a smaller diameter raise-bored shaft can be employed instead of a larger manually constructed/excavated shaft that would display turbulent air flow. The round shape also requires minimal additional rock support. Additionally, without the use of explosives - and therefore without the time required to ventilate-out blast fumes, bar down and install either temporary or permanent support - shafts can be finished in “one pass to final diameter”.

Raise boring fits perfectly within the requirements of mine production drilling. The method itself is safe, productive and simple. What more could anybody want? Indeed, the job can be completed in a single pass, with the resulting reduction in complexity alone providing many attractions to underground operators.

Despite the attractions for using raise boring for production work, it is still not being employed for this purpose. This article discusses the recent developments in raise boring and the effects that these may have on future underground mining. The raise boring application in mine production may not be brand new, but recent results may initiate a revolution in thinking, and possibly create a new mining standard.

Raise boring requires brute strength to break the rock. The cutting action is accomplished by applying more than enough thrust and torque against the rock through cutters installed on a reaming head. The various parts of the raise borer are heavy and bulky, and are therefore designed to be transported individually from one drill site to another. The set-up includes one or two power packs, a

control system, the raise borer itself, a base plate system providing attachment to the ground, many smaller tools and utility items, and all the drill string items. Naturally, the components form a functioning raise borer only after proper connections are made with hydraulic hoses, electric and control cables. In the past the number of connections was almost overwhelming, and include heavy hydraulic hoses with difficult to handle couplings. Luckily, the latest and most modern technology in hydraulic, electric, and control system design greatly simplifies connection and control solutions.

TRB-Raise Borers is a raise boring specialist which continuously researches new potential uses for its line of RHINO raise borers. The recent achievements with the RHINO includes a reduction by almost a half in the power pack size, offering incredibly powerful solutions despite a very small footprint. RHINO raise borers also utilise the latest cutting edge technology with CANOpen distributed control units linked with common bus. Such design upgrades have led to considerable simplification of the systems. Not only is the modern RHINO unit more robust and reliable than its predecessors, but it is also easier and quicker to move and establish as the required connections have been significantly reduced in number.

Unfortunately, a conventional raise borer cannot simply be carried from one site to the next. Instead, the new site requires preparation and planning. The construction starts typically with drilling and blasting as the raise borers often require higher than normal overhead space. Then, a concrete pad needs to be poured over firm rock although non-concrete solutions have recently become more common. Finally, basic supplies such as electricity are necessary for a successful raise boring operation and these need to be installed prior to the arrival of the raise borer. Sufficient water must also be provided for pilot drilling. A typical method is to construct a dam nearby, and pump returning water (with cuttings) to the dam. After the cuttings have settled, the water can be recirculated and re-used for flushing the pilot hole. Less obvious supplies on the drill site include proper lighting to allow safe working practices around the raise borer.

A good raise boring operation also includes safe and effective rod handling practises. Apart from the time taken for the raise borer's transport, drill string handling and rod changing are the greatest non-productive aspects of raise boring, and have also traditionally been the most hazardous. Modern remote controlled rod handling operation provides highest productivity, whilst reducing safety concerns.

While the erection of the modern raise borer can be achieved in just a couple of hours, nevertheless, the whole process is still a very long and complex process. In underground mines, the issue of transportation (even when using the most up-to-date raise borers) of so many different items may prove to be a huge challenge due to roadway congestion. In the best case scenario, the process still takes time.

Traditionally, the level of utilisation of raise boring changes as the mine develops. A typical mine is likely to see the largest raise boring projects during mine expansion. Most common applications include ventilation shafts, ore passes, media and utility holes.

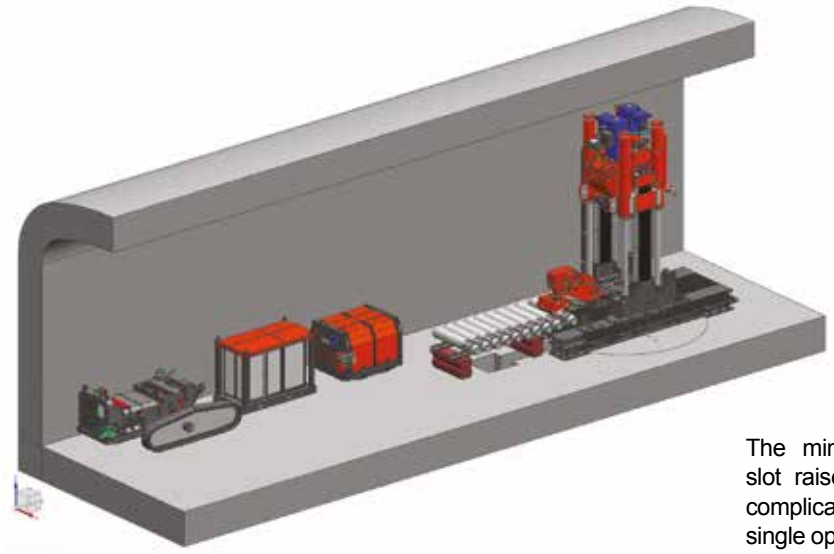
Typically, such shafts are large in diameter and long, taking several weeks to complete, as such the set-up time is insignificant.

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 (particularly when considering drilling relatively short lengths). Indeed, for typical production, it is impossible to justify the time and cost of daily raise borer transportation and set-up times.

However, slot raise drilling still remains the most suitable production drilling application for raise boring. Slot raises refer to relief holes within a stope, intended to provide void space (or burn-cuts) for blasting, thereby allow "expansion" of the blasted rock and to improve fragmentation. The benefits of larger diameter slots are well documented – but if only these slot holes could be produced simply and cost effectively, especially as these holes are much shorter in length and smaller in diameter when compared to typical raise boring projects.

Nowadays, there are several methods traditionally employed in mines to produce these slot raises: long-hole rigs, manual drilling methods, and even conventional raise boring to name but a few. Naturally, the chosen method depends also on the mining method being employed. A common denominator is often the complexity of the mining process, with multiple step operations being the least efficient. However, if you consider this function to be at the centre of any production initiative, then any improvement should be well received and immediately contribute to "bottom line" advantages.

Once the slot raise slot has been completed, the equipment can be dismantled and moved to the next drill site



A typical raise boring setup

So, to increase production in an underground operation, any slot raise rig must reduce the production complexities and simplify the mining process. Whilst the potential is certainly there, the challenge is to make raise boring (with its relatively short hole lengths) an appealing alternative.

To utilise the benefits of conventional raise boring whilst 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. This new unit had to include several capabilities: a rapid machine set up; to effectively drill holes that were suitable for production (or mine infrastructure development); and to be suitable for swift dismantle/relocation/set-up.

Such a unit would also not require a concrete pad, nor additional rock works, nor any special utilities or provisions other than the ones already established for the equipment operating in the same drifts. Additionally, the operation can ideally be performed by a single operator without any additional resources or dedicated equipment for assisting the raise boring operation. Sounds like a tall order?...maybe not.

Agnico Eagle Kittilä gold mine in Finland commissioned such a unit – reported to be one of the first mine in the world to do so. One of the drivers in their approach was a 30% higher annual production target.

Kittilä 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 that used for drilling blast holes.

The drop raises required 5 to 6 workdays (10–12 shifts) to construct, including all the drilling, blasting and hauling stages, and necessitated the use of two drill rigs and several members of a drilling/mining crew. Using long-hole drilling for the drop raises not only doubled the number of holes required (due to their smaller diameter) 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 explode during re-drilling.

Addressing this bottleneck (and reducing the operational complexity) was necessary if the mine was to achieve its production target of more than 140 stopes per year.

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 live detonators and explosives, because raise boring slot holes makes it unnecessary to blast at all before the actual production blasts.

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

The RHINO 100HM raise borer includes a comfortable, safe, quiet and ergonomic operating cabin. To further assist the operator, the most advanced controls are installed: the Rhino SMART operating system is a dedicated raise boring management software offering various features for operator, manager, maintenance personnel, and mine planner to improve production efficiency, optimise maintenance schedules, and maximise uptime. Additionally, almost unlimited number of cameras can be added to remotely follow the operation, if needed.

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 set-up follows much the same principles as with any mining jumbo or long-hole rig operation, (ie the same connections are used, and the raise borer utilises laser-assisted positioning after electric and water connections have been made). Hydraulic jacks and stingers are used to establish the drilling position with actual drilling staring immediately afterwards. Indeed, the first piece of drill string (complete with pilot bit) is already attached to the gearbox. This design integrates dust suppression and a muck chute to not only create a dust-free drill site, but also to take the cuttings away from the rig.

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 11-inch pilot bit and two raise boring cutters allows the raise to be completed in a single pass. The drilling concept utilises 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 out of forged and accurately machined high-alloy tool steel, allowing (if necessary) easy change of distance between the pilot bit and the reaming head. To maintain accuracy during drilling, replaceable

welded support plates are attached on the reaming head body, and wear pads on the stem. The unique features of this reaming head are its dimensions and its accurate gripping surfaces, specifically designed for perfect compatibility with the rod handling operation. As a part of its quick set-up and high productivity characteristics, rod handling in the RHINO 100HM is time-optimised by including a crane and a manipulator controlled (either with a wireless remote controller, or from an 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 100HM.

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, improved markedly; up to 8 stopes and 410.3m/month in October 2014, only three months after commissioning. The output over the entire year totalled 64 stopes, 11 mine infrastructure shafts and 2,993 drilled metres. On average 250 raise boring meters a month during the first year is a fantastic achievement, especially when the operators were still learning the technique, whilst further improvements were hampered as horizontal development became the bottleneck (instead of production drilling, as had previously been the case).

So how do these raise boring figures relate to the mining process?

“We now need only two blasts, even for those 40-metre stopes, and opening up the drop raises in five-metre breaks have been eliminated altogether,” Underground Planning Engineer, Elen Toodu points out. “Before Rhino, we couldn’t imagine blasting 145 stopes a year. Without it, we surely wouldn’t be that happy about the idea of mining at times more than 15 stopes a month. The stope cycle time has become significantly shorter. This has also freed up the long-hole rigs for drilling the actual blast holes instead of opening up drop raises. This job previously required 30% of our long-hole drilling capacity without adding 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. “[But] now every blast is a success”, Jani Ollikainen, Production Planner concludes.

“An additional slow-down [with the old method] was the insufficient accuracy of the long-hole rigs for the 40-metre sublevel spacing we have in certain areas. We can now open up the stopes much quicker, which is a major asset since the throughput time per stope is such a critical parameter in our operation,” explains Matias Suomela, General Supervisor, Underground Mine.

In reality “much quicker” means three times faster. Drilling both slot holes with RHINO 100HM only takes 2 days (4 shifts), instead of the 5 to 6 days (10–12 shifts) required for the drop raises by traditional long-hole drilling.

Jorma Kinnunen, the rig operator mentions that: “the planned change-over time of one to two hours from drill site to another, leaves a fairly generous leeway for transfers and routine maintenance, since the actual set-up normally takes no more than half an hour.” A work week for the RHINO 100HM typically includes drilling 4 slot raises; a total 120m of drilling in 5 days (5x2x10 h shifts) covering set ups, transfers, and demobilisations. Only one operator handles the rig at a time. No dedicated loaders, no supplementary equipment, and no utilities were assigned during that period for the raise boring process.

Rhino 100HM is a total solution for production drilling. One man operation is safe, productive and efficient

In conclusion, the success of 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. Obviously, the operators and managers at Kittilä have worked hard to understand the conditions and create the best solution for their operation, but also some kudos deserves to be given to the mine planning department for understanding the strengths of this new concept.

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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Salo’s experience in raise boring and underground operations comes from his involvement with Zinkgruvan (Sweden), LKAB Malmberget (Sweden) and Somincor (Portugal). He also spent 15 years in the US and Singapore, managing investment commodity sales and service operations.