Quality holes are the key to efficient blasting

When it comes to rock blasting in underground mining, control is paramount. From drilling and charging to detonation, safe and productive practices require careful step-by-step procedures.

Looking back in time, it is virtually impossible to imagine the evolution of mining and construction projects without the accompanying science of rock blasting, which first emerged in 17th century Europe.

At its most basic level, rock blasting involves the use of explosives applied to holes and chambers to split or remove rock mass of a predetermined shape and volume. It is essential to almost all operations and has, traditionally at least, been considered one of the most hazardous tasks in the underground work cycle.

Fortunately, today’s technology is a far cry from the days of gunpowder, later known as black powder, and unpredictable blasts. Although dynamite arrived on the scene in the mid 19th century and was introduced in mining operations, many people would continue to put their lives at risk over the next century.

To some extent, poor drilling quality also contributed to the hazards. In terms of safety, the 1970s marked the starting point for improved drilling practices as electro-hydraulic drill rigs began to replace pneumatic equipment. This, in turn, facilitated blastholes of a much higher quality.

Simultaneously, progress was driven by innovations such as ANFO (Ammonium Nitrate and Fuel Oil), a bulk explosive that is blown into the hole by high-pressure air, which soared in popularity and was followed by modern emulsions and slurries used for rock blasting.

Computerized systems are now also widely used in order to calculate charges and drilling patterns, which vastly improves the precision of blasts. At the same time, no level of proficiency in charging and blast design can make up for poor drilling, which serves as a first rule of thumb.

Control at every step

To uphold modern standards of safety, speed and accuracy, quality must be upheld at every step in the blasting process, and there is little margin for error.

A well charged drill hole is defined by an approach where all the aspects relevant to rock conditions and the task at hand have been carefully considered. This starts with the basic drilling parameters such as location, straightness and length of holes, percussion pressure, feed force and applied torque. These factors are crucial in the drilling phase and will have a large impact on the blasting operation as a whole.

Charging of holes, which is the next step, can be carried out relatively quickly, either manually using plastic/paper charges or, as in the case of bulk explosives, with mechanical charging equipment such as trucks featuring charging baskets, cable reels, hydraulic support legs and onboard compressors. Whatever method is used, it is important to dimension the size of the charges correctly so that the swell is ideally matched to the size of the void into which the blast is directed.

The most common methods of charging are:

- Cartridges (paper cartridge)
- Bulk
- ANFO
- Emulsion

The various explosives in cartridges are made up of nitro-glycerine, nitroglycol, watergel or emulsion-based products. These typically include paper cartridges, plastic hoses and plastic pipes.

Bulk emulsion explosives are composed of very small and dense droplets of ammonium nitrate and oxygen that are enclosed by a mixture of mineral oil and wax, called matrix. ANFO is the most commonly used explosive and is just as powerful as dynamite, but far less hazardous and more economical. It is, however, very sensitive to water.

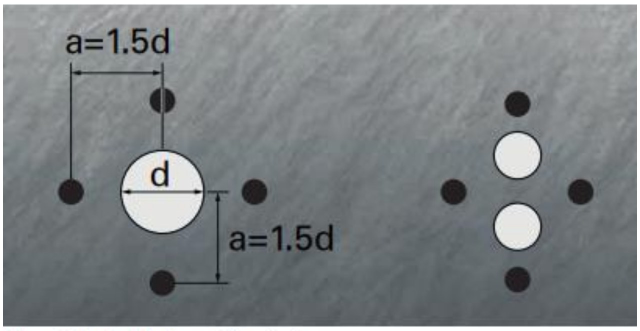


Figure 1: Typical designs of large hole cuts.

Parallel cuts for drifting

A variety of blasthole drilling techniques are employed in the underground environment that enable ore extraction through a system of drifts. A common technique involves drilling one or more large-diameter holes parallel to each other, acting as openings for small-diameter blastholes that are drilled in squares or in diamond shaped patterns, as shown in Figure 1, and is the hardest blast to fulfill.

In this case, the cut should be placed at the safest location on the tunnel face, as this will influence the rock throw (trajectory), the explosives consumption, and the number of holes needed for each round.

When designing the cut, the following parameters are important for a good result:

- Diameter of the large uncharged holes
- Burden
- Charge concentration
- Fire sequence

One of the parameters for good advance of the blasted round is the diameter of the large empty hole. An advancement of approximately 90% can be expected for a hole depth of 4 m, and one empty hole of 102 mm in diameter.

If several empty holes are used, a fictitious diameter of the opening has to be calculated, ideally in accordance with the formula $D = d\sqrt{n}$, where D = fictitious empty large-hole diameter; d = diameter of empty large holes and; n = number of holes.

V-cuts and fan cuts

The most common cut with angled holes is a V-cut, which refers to its V-shaped wedge pattern (see Figure 2). It involves a theoretical advancement per round that increases with the width, where 40–50 % of the tunnel width is achievable.

Double V-cuts, as well as triple and quadruple cuts for deeper rounds, are frequently employed. For an optimum pattern, the angle of the cut must not be too acute nor less than 60 degrees. Each cut should be fired with the same interval number, typically 50 milliseconds, using MS detonators to ensure good breakage and allow time for displacement and swelling.

The principle of the fan cut is to make a trench-like opening across the tunnel face. As the constriction of the rock is not as large as for V-cuts, fan cuts are easier to blast. For both cut types, attention must be paid to the tunnel width in order to accommodate the drilling equipment. Fan cuts, however, are not possible for small tunnels and long feeds.

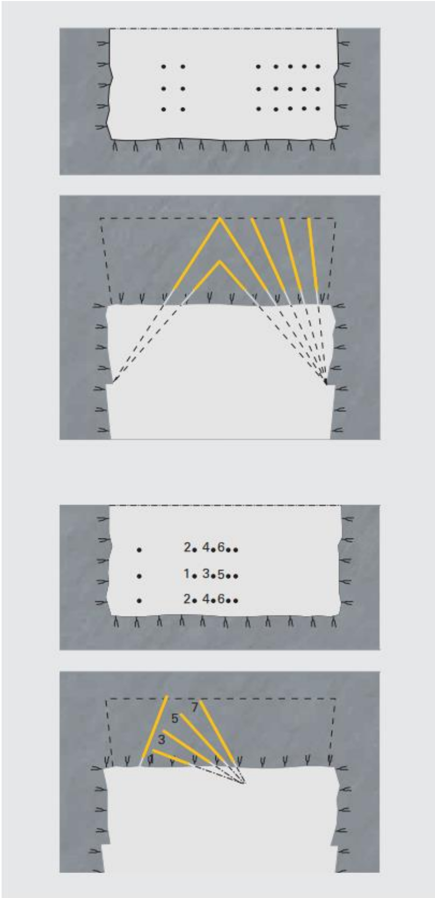


Figure 2: The principles of V-cuts and fan cuts.

Firing pattern

The firing pattern must be designed so that each hole has free breakage. The angle of breakage is smallest in the cut area, where it is around 50°. In the stoping area, the firing pattern should be designed so that the angle of breakage does not fall below 90°.

It is important in tunnel blasting to have sufficient time delay between the holes to allow time for breakage and throw of rock through the narrow empty hole, which takes place at a velocity of 40 to 60 m/sec. Normally, delay times of 75 to 100 milliseconds are used in the cut.

In the first two squares of the cut, only one detonator of each delay should be used. In the following two squares, two detonators for each delay may be used. In the stoping area, as can be seen in Figure 3, the delay time must be long enough to allow movement of the rock to generate space for expansion of the adjacent rock, typically 100 to 500 milliseconds.

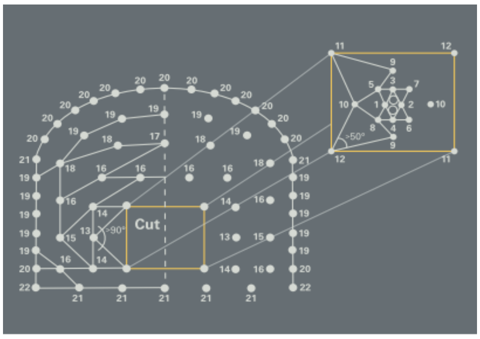


Figure 3: The numbers indicate a typical firing sequence with delays of 100-500 milliseconds for each hole.

Contour blasting

The contour of a drift is divided into floor holes, wall holes and roof holes, where two variants of contour blasting are used for wall and roof holes: normal profile blasting and smooth blasting.

With normal profile blasting, no particular consideration is given to the appearance and condition of the blasted contour, and the same explosives are used as in the rest of the round, but with a lesser charge concentration and with the contour holes widely spaced. The contour of the tunnel becomes rough, irregular and cracked.

Precision drilling, maximized uptime and several levels of automation are some of the key features of Atlas Copco's range of Boomer drill rigs.

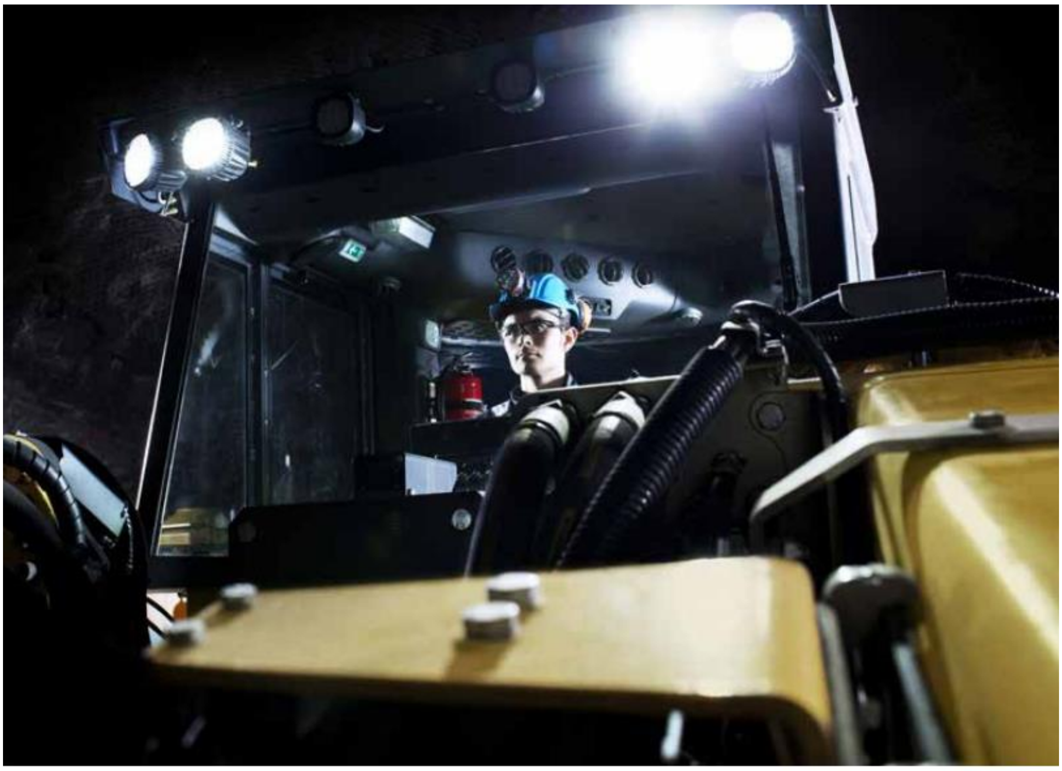
Although contour plays a lesser role in mining than in road or rail tunnel construction, good breakage coupled with rock reinforcement is an absolute must to ensure a safe working environment in drifts. In sensitive areas, smooth blasting, which is the second variant, is helpful as it creates fewer fissures in the remaining rock. In smooth blasting, the contour holes are drilled closer to each other than in normal profile blasting and are carefully charged with weaker explosives. This results in a smooth contour surface with fewer fissures in the remaining rock, which means that less rock reinforcement will be required.

Among the typical smooth-blasting explosives, the nitroglycerin-based, high-velocity explosive known as Gurit (containing kieselguhr, the original material that Alfred Nobel used to tame nitro-glycerine) has been widely used in the past. Today, however, this has mostly been replaced by string-charged emulsions that require less charging time and offer a range of safety benefits, such as reduced manual handling and storage and less noxious gas emissions.

Better technology means more precision

Deviation in the drilling of blastholes in the excavation of a tunnel from the intended theoretical line will lead to an increase in construction costs, with a direct impact on four main items: mucking of excessive rock material, primary shotcrete support, secondary concrete lining, and extended construction time.

Today, systems such as Advanced Boom Control ensure that blastholes are drilled accurately with respect to collaring, orientation, length and straightness. For drill rigs equipped with this technology, the true excavation line can be maintained more accurately, meaning some 10 cm closer to the theoretical excavation line than traditional techniques.



Systems such as Advanced Boom Control ensure that blastholes are drilled accurately with respect to collaring, orientation, length and straightness.

Initiating systems like NONEL have boosted safety levels due to their non-susceptibility to electrical hazards. Electronic detonators, however, are becoming a more and more popular alternative today due to the flexibility they provide for sequential blasting with set delays and intervals.

A long-standing challenge in underground blasting is toxic fumes. These are released at detonation as high energy in the form of heat and gas that is propelled through the rock. To combat the problem, modern emulsion explosives have been developed that are oxygen-balanced and generate a minimum of dangerous fumes, and far less smoke, which also means a reduction in ventilation time for safe re-entry.

When combined, the above factors contribute to a faster work cycle for drilling, charging, blasting, ventilation, scaling, support work, grouting, loading and transport. Nowadays, the drill face doesn't have to be marked up as these calculations are made via drill rig computers, which is just one example of the increasing role of automated processes in blasting.

This article has been produced with information sourced from Stig Olofsson's book Applied Explosives Technology for Construction and Mining, published by Applex.