DRILLING AND BLASTING

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STATE OF THE ART

Tunneling through solid rock may be performed either with a tunneling machine or by use of conventional drilling and blasting. Machine tunneling is comparatively new, having come into general use since the 1950s; the drilling and blasting method has been practiced for several centuries. This leads to speculation as to whether the machine will completely replace the older and more conventional method of tunnel excavation.

The complete obsolescence of underground drilling and blasting techniques does not appear to be imminent. Rock that is too hard to cut economically with a machine must be excavated in the conventional manner: using drills and explosives. Tunneling machines are expensive both to purchase and to install; consequently, they are frequently uneconomical in shorter tunnels. Furthermore, improvements resulting from research into drilling and blasting may likely bring wider adoption of conventional methods.

When the drilling and blasting method is used, the ground is shattered by the detonation of explosives within holes drilled into the solid rock. These holes are usually 25.4 to 50.8 mm (1 to 2 in) in diameter, spaced several centimeters to a meter apart in a preplanned pattern, and drilled to a depth that is dependent on the length of round to be pulled. Pneumatic percussion drills are customarily used. Small drills can be hand held, but larger and more powerful drills, which are now commonly used, must be mounted on positioning devices to obtain maximum drilling speed with a minimum of labor. Standard practice is to mount the drills on a carriage or “jumbo” that travels to and from the face on railroad tracks or on pneumatic tires.

Explosives for tunnel blasting can be either gelatine dynamite or ammonium nitrate. Detonation is accomplished by use of electric blasting caps with built-in delays. Delay refers to the short interval of time that occurs between the instant the electric current is applied and the instant of explosion, which may vary from zero to several seconds. The use of delays results in sequential loosening and ejection of the shattered rock during the blast, which starts with a “cut” shot near the center of the face and progresses in a series of shots outward to the tunnel perimeter.

Drilling and blasting is cyclical. To excavate a round requires the sequential operations of drilling the holes, loading the explosive, detonating the blast, and finally removing and disposing of the broken rock, installing supports (when needed), and extending utilities. The aim of the tunnel engineer is to reduce the cycle time to a minimum, thereby permitting a maximum number of rounds to be “pulled” in a 24-h day and keeping the cost of tunneling as low as possible.

Since 1930 many improvements have been made in excavating tunnels by drilling and blasting. Consequently, tunnels are today being driven twice as fast and sometimes with less labor than they were 40 years ago. Improvements during these years include the drill jumbo, removable drill bits, tungsten carbide bit facings, better drill steels, larger and more powerful pneumatic drills, hydraulically powered booms for positioning of drills, larger and faster mucking machines, devices such as “cherry pickers,” and the sliding floor (magic carpet) for faster switching of muck-hauling vehicles. These improvements were the products of equipment manufacturers and inventive tunnel engineers and were not publicly financed. The increased tunneling activity today and the stimulus of publicly financed research may bring even greater advances in conventional tunneling methods during the next decade.

Tunnel jumbo equipped with hydraulic drills (photo courtesy of Atlas-Copco).

FUTURE RESEARCH

Faster Drilling

Accelerated research into improved metallurgy of drill bits, differently shaped bits, and faster drills could increase substantially the currently attainable drilling speed. Rotary drills might replace percussion equipment in hard rock work. Experiments in the past with rotary drills were discouraging largely because of the harmful effect of noise on the human operator. Research into noise abatement might lead to discoveries that would result in a reevaluation of rotary drilling.

Automation of Drilling Mechanisms

Programmed positioning of drill holes could eliminate delay now caused by human factors such as the experience, intelligence, or state of fatigue of the operator.
Mechanical Loading of Explosives

One of the factors that increase labor costs in tunnel construction is the number of workers required to hand place and tamp the explosive charge. Machines to place the charges could result in significant savings in labor cost and loading time.

Hydraulic Drills

Manufacturers have recently introduced hydraulically powered drills and impact breakers that give great promise of success. Perhaps further experimentation with combinations of percussion drills and impactors of expansion breakers will lead to a new rock-breaking technique that will eliminate the need for explosives.

Smooother Excavation

One of the advantages of machine excavation is the elimination of overbreak. The removal of unnecessary material beyond the required excavation lines increases the cost for labor and ground supports and especially adds to the cost of concrete lining required to fill those unwanted spaces. Further research is needed in methods to permit better control of overbreak.

Faster Muck Removal

Little improvement has been made during the past 40 years in mucking machines. Faster production could undoubtedly be obtained by introduction of already known principles to tunnel excavation. Use of hydraulically powered and more compact shovels could result in faster and less costly handling of materials in underground excavation.

Labor Efficiency

A program of education and improved relations between employer and workers is needed to increase labor efficiency, improve safety, and reduce costs. An objective study should be made to determine the optimum number of workers required for various tunneling operations. Part of the high costs of underground excavation results from requirements of union management that more workers be employed than needed for efficient and safe operations with today's equipment.

Measuring Surface Vibrations

Vibrations at the surface of the ground are caused by blasting for rock tunnels. The character of these vibrations cannot now be accurately predicted, and a measurement method is needed, particularly when blasting occurs under densely populated areas.