TUNNEL GUIDANCE

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STATE OF THE ART

The control of alignment and grade during underground construction operations is a highly specialized application of the surveyor's art. Investigation of the ruins of ancient tunnels reveals that 2000 years ago the Romans skillfully guided their subterranean excavations by use of primitive surveying techniques, some of which can now only be guessed at. Today, as tunnels are being bored all over the world for various purposes, we have much more sophisticated equipment to aid us.

Even the finest of equipment, however, is useless without the knowledge and skill of the surveyor. Those who believe that the laser, electronic distance measuring, and instruments such as the gyrocompass are about to eliminate the human factor are misguided.

The use of the laser as a construction alignment aid came into common use in the 1960s. Many models and systems have been devised and tested, and laser guidance techniques today are greatly improved over earlier efforts. The low-powered laser beam, which can be used safely with reasonable caution, is basically an unbreakable string line. It is peculiarly suited to tunnel work. The low light level, plus the presence of humidity and dust particles in the air, makes the line itself quite visible. In most cases it is located out of the way of the heaviest action; but, should it become obstructed or disturbed, that fact is immediately evident.

One of the positive advantages in the use of the laser beam lies in its visibility. In machine-driven tunnels the spot on the targets is positioned so that the mining equipment operator can readily see and be guided by it, and the tunnel engineer or foreman can also become immediately aware of any variation. Another advantage is that the operator does not become involved in computations and can concentrate on the positioning of the machine by visual means.

Guidance of straight tunnels by means of laser beams is comparatively simple. When a tunnel alignment includes complex curves both horizontally and vertically, a characteristic of transportation structures, the task of steering the boring machine or shield becomes more difficult. The Tunelaser method, a proprietary system developed during construction of BART, has successfully solved the problems of guiding tunnel driving equipment around curves as well as on the straightaway.

In this system two targets are mounted, one forward and one aft, on the mole or shield, carefully located horizontally and vertically in reference to the axis of the machine. They are usually spaced so that the operator is between them. The rear target is transparent. Since it is rarely possible to place these targets on the centerline axis, they are normally located on an offset in one of the upper quadrants of the machine, which keeps them away from conveyors and workers. Many machines have personalities of their own, causing them to dive or drift. The operator can make minor adjustments of position of the spot on a target to counteract this problem. Since no sophisticated thinking or computation is required, the operator can concentrate on mechanical controls.

Primary underground survey control between the entrance and the laser stations still depends largely on the use of optical surveying instruments such as transits, theodolites, and precise levels. In place of the old and laborious hand-chaining method for measuring distance along the tunnel line, many tunnel surveyors are making use of modern devices using reflected beams of plain or laser light. The North Seeking Gyro, a spin-off from space age technology, is becoming more and more important to the mine surveyor and underground mapper, particularly in deep and multilevel mining operations. By furnishing a direction, or azimuth, while completely underground, with relatively close precision, it eliminates many of the laborious methods heretofore used.

Precise surface control to ensure accurate meeting of tunnel headings and to locate the tunnel with reference to appurtenant structures has been improved and speeded by wide use of modern theodolites, precise levels, and sophisticated distance-measuring instruments using electronic and light-beam techniques in place of old-fashioned triangulation and hand chaining.

FUTURE RESEARCH

New Guidance Concepts

It is not impossible to visualize that one day a master controller will be developed by using the components available now. Some combination of gyro, computer, laser, and guidance equipment in use today in the space program or some completely new concept will be adapted in the relatively near future to guide the innumerable tunnels yet to be bored.

Automatic Steering of Equipment

There seems to be need for improvement of feedback mechanisms with which a tunneling machine can be steered automatically without having to feed signals through the eyes, brain, and hands of the operator. Some work has been done in this direction. Most of the required technicians are already known to the computer, electronic, and aerospace industries. Probably the principal need is for a knowledgeable organization to apply such methods to tunnel construction equipment, which is daily becoming capable of faster and faster rates of advance.

Transmission and Display of Alignment Information

There also seems to be a need for electrical or electronic devices capable of transmitting and displaying instantaneous tunnel alignment information to stations remote from the face. For instance, a superintendent in an office on the surface would be able, at any moment, to observe, perhaps on a digital display panel, the progress and course of heading equipment and thus be relieved of much worry.