TUNNELING IN BAD GROUND

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STATE OF THE ART

When tunnelers use the designation "bad ground," they are referring to ground that has adverse geological characteristics that make optimum construction progress impossible. In rock tunnels, these negative characteristics include

1. Rock that is badly fractured and jointed;
2. Rock that is disintegrated;
3. Rock that is subject to chemical or physical change or both in the presence of air and water;
4. Squeezing rock that tends to move under pressure into the excavated space;
5. Swelling rock that is a combination of rock of items 3 and 4 in that an actual increase in volume results from exposure to air or water;
6. Running ground or material that is so finely divided that, under action of water and ground pressure, it actually flows into the excavated space;
7. Physical conditions that permit large inflows of water to enter the tunnel; and
8. Explosive or poisonous gases.

If rock is badly fractured, jointed, or disintegrated, support must be installed immediately, and the length of round must be reduced. Measures must often be adopted to inhibit the caving of the face. Because of the need to continually excavate at the face, supporting the face presents a different and more difficult task than supporting the tunnel perimeter. A variety of techniques have been developed to temporarily support the face or a portion of it. This is usually accomplished in an earth tunnel by a shield at the front of which are mounted breast jacks. As the shield is shoved ahead, the jacks provide constant pressure on the face supporting it. In a rock tunnel, the tunnel boring machine provides the pressure on the face to support it. Unfortunately, in most cases in which the ground is bad enough to require face support, the tunnel boring machine is not an effective tool to excavate the tunnel.

Effective face support is difficult to provide in a rock tunnel that is being excavated by drilling and blasting. A breasting jumbo has been used in some instances, but the procedure commonly used entails the mining of the tunnel in several passes or drifts. The area of the exposed face is thus minimized, and the excavation of the tunnel is facilitated. Although this procedure provides the most safety, it is obviously time consuming and is therefore expensive.

Large inflows of water or the presence of explosive or poisonous gases can stop tunnel excavation altogether until the ground can be grouted to seal the fissures through which the water or gas is flowing.

In soft ground tunnels, groundwater most often creates bad ground. In the presence of any appreciable head, water will usually flow into the tunnel and will carry soil with it unless measures are taken to prevent the flow. If water is permitted to flow into the tunnel carrying soil with it, subsidence of the ground surrounding the tunnel will result and, in most cases, substantial damage will be incurred.

The flow must be prevented and can be accomplished in several ways. The first and most common way is to predrain the ground or dewater. A variety of techniques can be employed depending on the geological conditions. If the soil is relatively impervious, predrainage may not be feasible. Fortunately, except for soil materials of low shearing strength, the impervious nature of the soil will itself usually ensure that there is no major flow problem. Predrainage can be relatively difficult, if not impossible, if within the cross section of the tunnel there are pervious soil materials overlying impervious soil materials or rock.

Another way to deal with groundwater is to use the compressed air or plenum process. This involves the introduction of compressed air into the tunnel at a pressure sufficient to balance the head of the groundwater. Because of labor union, legal, and medical restrictions with respect to working hours and decompression times for workers, this method can be costly. Another disadvantage of using compressed air is the potential health hazard to the compressed air workers. In recent years progress has been made with respect to the reduction of this hazard mainly by increasing decompression times.

The presence of undesirable gases such as methane or hydrogen sulfide is common in soft-ground tunnels, particularly in tunnels driven through ground of organic origin. Because of the danger of explosion, poisoning, and asphyxiation, measures must be taken to normalize the tunnel atmosphere. The usual procedure to accomplish this is to provide large quantities of ventilating air to keep the concentration of gases low.

All cases of bad ground whether in rock or in earth are more effectively dealt with if the existence of negative characteristics is known before work starts. Equipment and methods can be selected and devised to deal with the conditions or combination of conditions that will be encountered. If encountering bad ground is a surprise, then the work may have to be stopped and the methods and equipment, and perhaps the contract under which the work is being performed, may have to be modified.

FUTURE RESEARCH

Geological Exploration

The ability to predict the presence of bad ground is important so that the element of surprise is eliminated and proper plans can be made to deal with the bad ground. Improvement in present techniques and development of new techniques for exploration and interpretation are needed.

Equipment for Use in Bad Ground

Tunnel boring machines are most effective and productive in reasonably uniform ground conditions. Often in bad ground, the boring machine cannot excavate properly and gets in the way of conventional equipment that can work more effectively in bad ground. If boring machines can be

developed that can operate efficiently in both good and bad ground, considerable savings will be realized.

Ground Stabilization

Bad ground can often be stabilized by means of chemical consolidation or ground freezing, but these procedures are expensive and time consuming. Research directed toward reducing the costs and improving the technique can be rewarding.

Face Stabilization

If a method or technique can be developed by which the face can be quickly treated from within the tunnel to make it sufficiently stable to stand unsupported for the relatively short time necessary between blasts, material savings in time and cost can result.