Tunnel

Tunnels are underground spaces, usually, in a tubular shape with substantial lengths. They can either be man-made or natural and can be used as passageways, storages, carriageways and utility ducts. They can also be used for mining, water supply, sewerage, flood prevention, civil defense, and many other purposes.

Man-made tunnels can be constructed in numerous ways. Shallow tunnels are usually constructed by burying tunnel structures in trenches dug for the purpose. This is a preferred method of tunnelling as long as space is available and the operation will not cause disturbance to surface activities. Otherwise, tunnels can be constructed by boring through the ground. Short tunnels are usually bored manually or by using light machines, such as roadheader, backhoe, etc. If the ground is too hard to bore, drill-and-blast method is frequently used. For long tunnels, it is more economical and much faster to use tunneling boring machines (TBM) which work on full face at the same time. In uniform massive rock formations without fissures or joints, tunnels can be bored without any temporary supports to hold up the tunnel crowns. However, more than frequently, temporary supports are required because of the presence of fissures and joints in the rock mass. Figure 1 shows the temporary supports for a 4-lane highway tunnel. In recent years, it has become popular to spray a layer of shotcrete to serve as the primary lining to protect the newly exposed surface and to support the tunnel crowns as well. The shotcrete is frequently reinforced by steel meshes and, if necessary, braced by steel lattices.

In soft ground, it has become popular to use shield machines for boring and reinforced concrete segments, see Figure 2, for lining. The largest shield machine ever, 14.14m in diameter, was used in constructing the Tokyo Trans-Bay Highway (Tokyo Wan Aqua-Line) between Kawasaki City and Kisarazu City of Japan (completed in 1997). There are various types of shield machines available to serve different purposes. Figure 3 shows the multi-face shield machine first used in constructing the Osaka Business Park Station of No. 7 Subway Line of Osaka, Japan (completed in 1995). The machine is 17m in width and 7.5m in height and has three cutters which operated independently. Theoretically, the two side cutters can be detached from the center cutter upon the completion of station excavation leaving the center cutter to continue boring towards the next station. However, this technique was not used in this particular case and the machine was used for constructing the Osaka Business Park Station only.

Immersed Tunnels

For tunnels to be constructed across waters, an alternative to boring is to lay tunnel boxes directly on the pre-prepared seabed. These boxes, made of either steel or reinforced concrete, are prepared in dry docks and sealed at their ends by the use of bulkheads. They will float as the docks are flooded and will be towed to the site by tugboats. The boxes are then flooded to allow them to sink to the seabed after they are properly positioned. Usually, immersed tunnels are buried in shallow trenches dug for the purpose and covered by ballast so they will not be affected by the movement of the water. The joints between sections of the tunnel will be made watertight by using rubber gaskets and water is pumped out for the tunnel to be ready for services. Among the numerous immersed tunnels, the newly completed one (3510m) for ϕresund Link between Denmark and Sweden is second to the cross-bay tunnel (5825m) for the Bay Area Rapid Transit of San Francisco in length.

Micro-tunnels

Small size tunnels, such as sewer lines and water mains, are usually installed by jacking steel or concrete pipes into the ground as illustrated in Figure 4. The soil core inside the tubes can be removed manually or by using moles, which are essentially small shield tunneling machines. The alignment of the pipes is continuously monitored and adjusted. With the moles guided by computerized navigation system, it is possible to align pipes to a precision within 100mm regardless of length. This technique has been used for jacking pipes as large as 2m or so in diameter for distances more than 100 meters. Pipes with smaller sizes can be jacked to distances of more than 300 meters.

Special Tunneling Techniques

Auxiliary measures are frequently required to ensure the safety of tunnels during boring in soft ground. In the early days, compressed air was a popular choice. It is seldom used nowadays because improper decompression may cause aeroembolism (diver’s disease) to workers. Instead, grouting and ground freezing are now favored. In the Central Artery Project (scheduled to be completed in 2004) in Boston, ground freezing is carried out to permit three tunnels to be bored under the railway tracks leading to Boston's South Station Railway Terminal. There are a total of roughly 1,600 freezing pipes installed to depths varying from 13.7m (45 feet) to 16.8m (55 feet) and the volume of frozen soil is more than 60,000 cubic meters. This could be the largest undertaking of this nature.

An underpass, scheduled to be completed in the year 2001, is being constructed beneath the Taipei International Airport by using the Endless-Self-Advancing method patterned by Uemura Engineering Co., Ltd of Japan (Moh et al, 1999). As illustrated in Figure 5, to minimize ground settlements and to ensure the safety of air traffic, interlocked steel pipes are first jacked into the ground to form a protective shelter. The soil core inside the shelter is excavated for 400mm per lift. Concrete segments are moved consecutively in sequence into the space created, one by one, by jacking against the segments behind. Each time only one segment is jacked forward and the jacking force is taken by the frictional resistance acting on all the rest of segments. Cables are anchored to the first and the last segments so the force acting on the last segment can be transmitted to the segments in front of the one being jacked. The movements of segments resemble the movements of centipedes and, in theory, there is no limit on the length of tunnel to be installed.

The Longest Tunnels

The longest tunnel of any kind is the New York City West Delaware water supply tunnel (completed in 1944). It runs for 105 miles from the Rondout Reservoir into the

Hillview Rreservoir in Yonkers, New York. The longest rail tunnel is Seikan Tunnel (53.6km) in Japan (completed in 1985). The longest road tunnel is Saint Gotthard Tunnel (16.9 km) in Switzerland (completed in 1980). The title will be taken over by Laerdal Tunnel (24.5 km) in Norway in the year 2001 upon its completion.

The longest undersea tunnel is the Channel Tunnel (49.4 km of which 38 km is undersea) across the English Strait. It runs from Folkestone on the Britain side to Calais on the France side. There are two running tunnels plus one service tunnel in the center, 7.6m and 4.8m in internal diameter, respectively. The Tunnel was officially inaugurated on May 6, 1994 when Her Majesty the Queen of England and President Mitterrand of France became the first official passengers to pass by train between the two countries. Eurotunnel has a concession from the British and French governments to run the Tunnel until 2052. Shuttle trains will carry up to 180 cars, or 120 cars together with 12 coaches. Freight shuttles can carry 28 lorries. It will take 35 minutes to cross the strait.

References

Moh, Z. C., Hsiung, K. I., Huang, P. C. and Hwang, R. N., (1999) Underpass beneath Taipei International Airport, Proc., Conference on New Frontiers and Challenges, 8~12 November, Bangkok, Thailand

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Figure 1 Temporary Supports to a 4-lane Road Tunnel
(Courtesy of RESA Engineering Corporation)

Figure 2 Reinforced Concrete Lining for a Tunnel

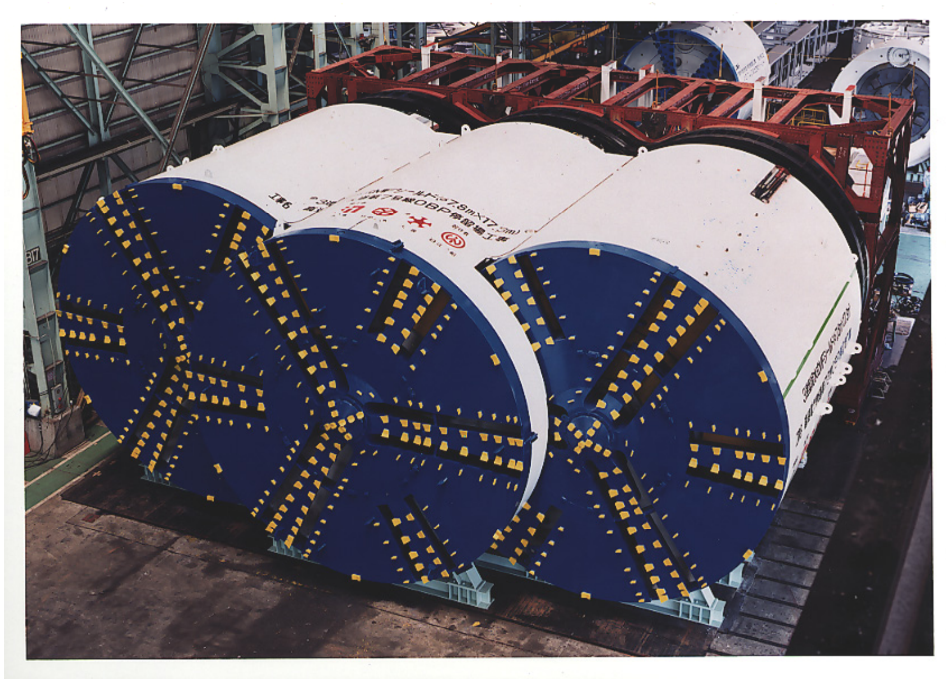

Figure 3 Multi-face Shield Tunneling Machine
(Courtesy of Hitachi Zosen Corporation)

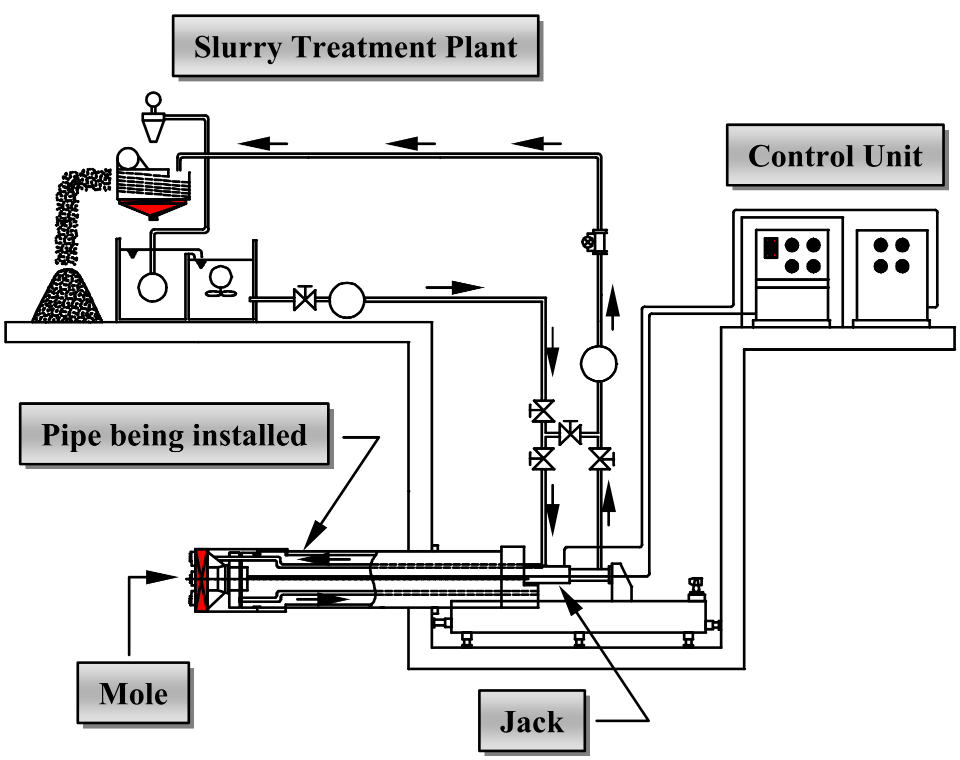

Figure 4 Micro-tunneling and Pipe Jacking Technique

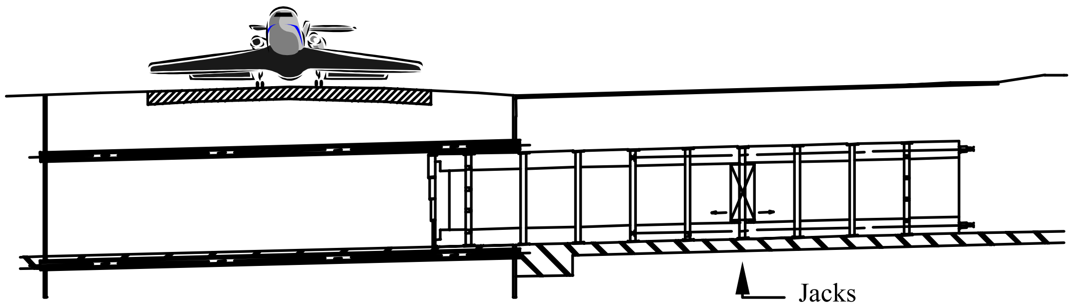

Figure 5 Endless-Self-Advancing Tunneling Technique