Immersed tube tunnels are composed of prefabricated sections placed in trenches that have been dredged in river or sea bottoms. The sections are usually constructed at some distance from the tunnel location and made watertight with temporary bulkheads. They are then floated into position over the trench, lowered into place, and joined together underwater. The temporary bulkheads are removed, and the trench is backfilled with earth to protect the tubes. Immersed tubes have been widely used for highway and rail crossings of soft-bottomed, shallow estuaries and tidal rivers or canals in which trenches may be excavated with floating equipment.

**GENERAL DESCRIPTION**

Under favorable conditions, the immersed tube method is the most economical construction for any type of underwater tunnel crossing. Tunnel sections in convenient lengths, usually 300–450 ft (Denmark’s Guldborgsund Tunnel has the longest element length, 690 ft), are placed into a predug trench, joined, connected, and protected by backfilling the excavation. The sections may be fabricated in shipyards on shipways, in dry docks, or in casting basins depending on the type of construction and available facilities. A prerequisite for this method is a soil with adequate cohesion, which permits dredging of the trench with reasonable side slopes that will remain stable for a sufficient length of time to place the tubes and backfill.

The top of the tunnel should be preferably at least 5 ft below the original bottom to allow for an adequate protective backfill. Where grade limitations and bottom configuration make this impractical, the tunnel may project partly above the bottom and be protected by a backfill extending about 100 ft on each side of the structure and confined within dikes. The fill must be protected against erosion by currents with a rock blanket, protective rock dike, or other means. There have been cases where ships in confined channels have used anchors as turning pivots in wharfing operations. This practice, although contrary to navigation rules, may require deeper backfill over a tunnel in such a location or special protection by rock cover, concrete slabs, or other means.

Tides and currents must be evaluated to establish conditions to be met during dredging and tube-sinking operations. Nearby shellfish areas must be identified so precautions can be taken during construction to prevent damage from silting due to dredging or backfill spillage.

Dredging and backfilling operations should be executed so as to minimize disturbance to the natural ecological balance at the construction site. Permits for construction and jurisdictional conflicts with other governmental agencies over environmental protection, natural resources, and local conditions must be evaluated and resolved. Approval of these agencies should be obtained during the preliminary design stage.

**Historical Perspective**

The first use in the United States of immersed tube tunnel construction methods was for a water tunnel crossing the Shirley Gut in Boston Harbor in 1896. The first transportation tunnel constructed by immersed tube methods in the United States was the Michigan Central Railroad Tunnel under the Detroit River, completed in 1910 under the direction of William Wilgus. Another early immersed tube was the Harlem River crossing of the New York Subway, completed in 1914, presently part of the IRT Lexington Avenue line.

The first highway immersed tube in the United States was the Posey Tube, a concrete tube section, between Oakland and Alameda, California, completed in 1928. In 1930, the Detroit–Windsor Tunnel, a highway link between Detroit, Michigan, and Windsor, Ontario (Canada), was completed. This tunnel’s octagonal double steel shell cross section became the model for widespread use of similar construction methods for steel tube tunnels, including

- Three two-lane tunnels under the Elizabeth River between Norfolk and Portsmouth, Virginia (1952, 1962, 1988)
Immersed Tube Tunnels

After much discussion of concrete tubes in the United States over the years, Boston's Central Artery project will include a concrete subaqueous tunnel under Fort Point Channel. The tunnel crossing includes two 460-ft-long tube elements to be placed side by side on a caisson foundation. This unique structure will be the first concrete tube realized in the United States since the Posey Tube. The Deas Island Tunnel near Vancouver and the Lafontaine Tunnel at Boucherville, near Montreal, provide two Canadian examples of concrete tube construction in North America.

The first immersed tube tunnel built in Europe was the Maas Tunnel in Rotterdam, The Netherlands. In 1929 the municipal council of the city of Rotterdam commissioned three engineers, Van Dijk, Van Dunne, and Von Bruggen, to visit the United States to study new tunnel construction methods as part of the planning for the Maas Tunnel project. A contract was awarded in February 1937 to an alternative bid for a concrete tunnel with rectangular cross section, replacing the original design of two separate, two-lane octagonal double-shell steel tunnels very similar to the cross section of the Detroit-Windsor Tunnel. The Maas Tunnel was completed in 1942.

By 1986, at least 67 immersed tube road and rail tunnels had been completed worldwide. Of these, 32 are steel shells and the remainder, concrete (Culverwell, 1989). The International Tunneling Association's 1993 state-of-the-art report provides a technical inventory of 91 immersed tube tunnels completed since 1910 (ITA, 1993).

CONCEPTUAL CONSIDERATIONS

Alternative Tunnel Concepts for Subaqueous Crossings

All tunnel projects involve their own special problems. There is a wide range of conditions for which immersed tubes have been found suitable. However, immersed tubes are not invariably the best alternative for all underwater tunnels. Concept selection for underwater transportation tunnels generally requires performance of "alternative concept analysis" for comparative evaluation. Although their range of applications overlap, there are three proven and practical alternatives available:

- Bored or mined tunnels (generally in rock)
- Shield tunnels (generally in soft ground)
- Immersed tube tunnels

The relative suitability of each of these methods will depend primarily on the hydrographic and geotechnical conditions of the project site.

Recently, a number of floating tunnel alternatives have been studied for a fixed-link crossing of the Straits of Messina in Italy and for Hosfjord Crossing in Norway. These studies have advanced to a point where technical feasibility has been established. Realization of a floating tunnel project awaits economic and political decisions.

Several topics and parameters influence the selection of tunnel type among the alternatives listed above. These include, but are not limited to, required navigable depth and traffic volume of waterway, shoreline infrastructure, site topography, geology, and geotechnical considerations; special risks created by the (inexhaustible) water supply overhead during construction and service life; approach gradients and lengths; acceptable grades; ventilation requirements, and power usage by tunnel facilities and by vehicles using the tunnel. Some of these considerations have been discussed in Chapter 2. Ventilation is covered in detail in Chapter 20.

The required navigable depth establishes the absolute minimum tunnel depth below the water surface. The waterborne traffic volume affects the possible use of intermediate ventilation islands and the type and use of floating construction equipment.

The immersed tube tunnel invariably can be located the least distance below the water surface, generally minimizing the length of project affected by the water barrier. As discussed elsewhere in this chapter, immersed tubes need only a nominal allowance for protective backfill below the sea or river bed; where the water depth is substantially more then navigation requires, part of the tube cross section may actually be above the original bottom. Shoreline infrastructure affects terminal locations of tube-type tunnels and locations of ventilation structures for all alternatives.

Site topography affects approach gradients and may negate the otherwise pronounced advantages of a tunnel at minimum depth below the water surface. For example, a fjordlike shore topography will require long lengths of land approaches, thus allowing subaqueous (floating) tunnels an economic advantage.

Geology plays an important role in choice of alternative. In general, the poorer the subsurface geology, the more favorable a tube becomes. Rock depth below the water surface...