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Technical note

The challenges involved in concrete works of Marmaray immersed tunnel with service life beyond 100 years

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ABSTRACT

Marmaray immersed tube crossing, located at the entrance of Bosphorus Strait of Istanbul, will be one of the unique infrastructure facility bringing great engineering challenges in immersed tunnel technology. The employer requires a minimum design life of 100 years for the immersed tunnel structure that will be under exposure of the highest saline water pressure at the depth of 58 m that has never been experienced yet in the history of immersed tube systems. Since the structural concrete is to be subjected to extremely aggressive environmental conditions during expected long-term service life, the quality assurance of the immersed tunnel has been ensured by setting a series of effective technical requirements taking into account the potential durability risks and predictive models in design phase, outputs of pre-testing activities and potential difficulties at construction period. The objective of this paper is to present some major steps involved in concrete works of this megaproject by giving the highlights from laboratory scale researches to the execution of the work at construction site.

1. Introduction

Marmaray Project Contract BC1 comprises design and construction of 9.8 km long underground tunnel, 2.4 km long cut-and-cover and 1.4 km long immersed tube connecting Asia and Europe under the Bosphorus Strait with railway crossing as illustrated in Fig. 1.

Marmaray immersed tube crossing will be the deepest tunnel of the world with its unique depth of 58 m. Fig. 2 compares the depths of the some existing immersed tube tunnels. Water intake of the external tunnel elements is strictly not allowed since watertightness is the key performance parameter of the long-term durability. However, watertightness of the structure cannot be solely controlled by using a concrete with very low water-binder ratio. Construction with a crack free concrete is also essential for the water retaining tunnel elements under exposure of very high water pressure. On the other hand, Bosphorus Strait is a potential location for a great seismic event with a very high probability of occurrence within 100 year service life of Marmaray immersed tunnel. These extra-ordinary facts of this tunnel have put the designer into a great challenge to find the most effective solution that will ensure both expected long-term durability and seismic safety.

The achievement of a successful concreting operation for such long-term durability structure under severe conditions has been realized by the effective management of the following phases; detailed design of immersed tunnel, selection of relevant codes for testing performance of constituent materials, supplying constituent materials meeting needs of modern concrete technology, design of concrete mixture ensuring both high early-age and long-term performance, performing full scale site trials prior to execution of actual works for verification of material performance and workmanship quality, and execution of the best practice in the actual works under the light of lessons learnt from lab scale studies to the full scale site trials. The work presented in this paper gives some insight into the challenges on the above mentioned areas of Marmaray immersed tunnel project.

2. Detailed design of the Bosphorus immersed tunnel

2.1. Design principles

The design needed for the execution and completion of the works must ensure that the works are fit for their intended purpose. Some of the major principles taken into account in execution of the detailed design are as follows:

- The design must be in conformance with the construction methods.
- Industrialized methods and innovative solutions within existing technology must be adopted where practicable.
- Designs, materials and methods of construction must be of recognized and well-proven nature.
- The design must be safe, robust, reliable and durable (ERQ, 2004).

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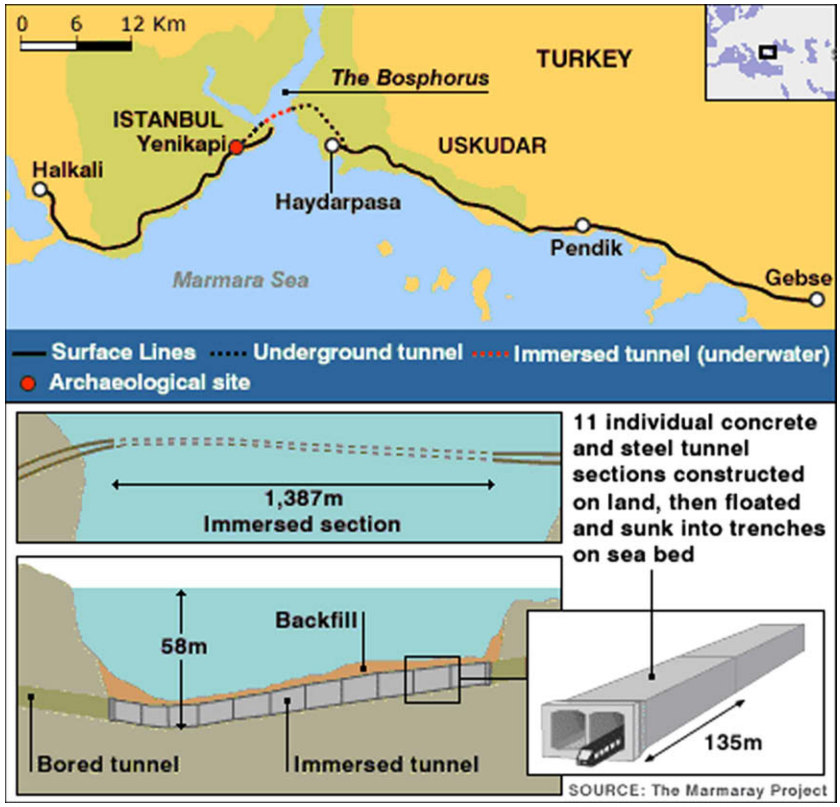

Fig. 1. Scope of the Marmaray Project Contract BC1.

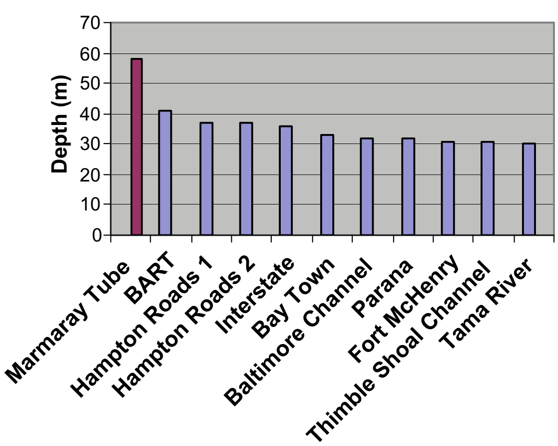

Fig. 2. The depths of major immersed tunnels in the world.

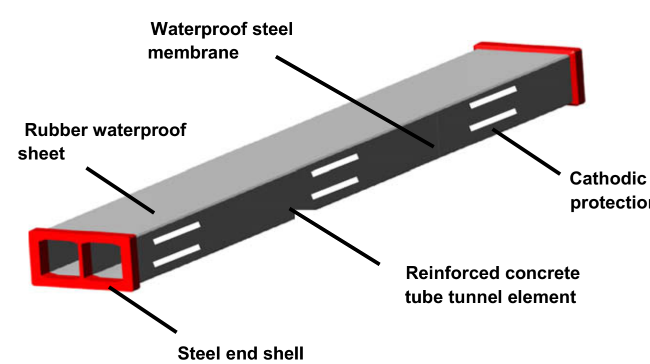

Fig. 3. Basic layout of immersed tube element.

2.2. Structural details

2.2.1. General information

Marmaray immersed tunnel consists of 11 tube elements (E1–E11) varying 98.5 to 135 m in length. The cross-section of the tunnel elements is 15.3 m wide by 8.6 m high that is capable of accommodating two rail tracks separated by a central wall. Figs. 3 and 4 show basic layout and rectangular cross-section of the immersed tube element, respectively. The thickness of the major reinforced concrete sections of the tube elements are as follows:

- Base slab: 900 mm
- Side walls: 1000 mm
- Inner wall: 600 mm
- Top slab: 800 mm.

2.2.2. Steel end shell and joint section

The steel shell at the end of the tunnel element was fabricated with a steel-concrete sandwich structure in the geometry illustrated in Fig. 5. A steel end shell consists of nine prefabricated sections. The open ends of the tube elements were wrapped with bulk head. The end shells were designed to accommodate gasket beam. The gasket beam serves to hold rubber gasket as a temporary seal. The function of the rubber gasket is to ensure smooth connection and watertightness between two tube elements during the period from the sinking of the elements to the completion of the permanent works. After immersion, permanent seal of the joint section was provided by a watertight (steel) plate that is to be covered