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Marmaray project: Tunnels and stations in BC contract

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Abstract

Istanbul is one of the most famous historical cities in the world. However, the project alignment selected as the best of a range of alignments cannot avoid passing beneath the historical and cultural heritages of Istanbul as well as under ancient and densely inhabited areas of the city. This paper will explain some of the challenges related to the bored tunnels.

Historical buildings are vulnerable. Yet many existing residential and office buildings are old and constructed on minimal foundations. As a consequence, it is vital that any drawdown of groundwater and any ground settlements have to be minimized.

In addition, the connection between the immersed and bored tunnels will be made directly and totally underground, without the usual intermediate shafts and beneath the deep waters of the Bosphorus Strait. This operation needs the utmost control of the tunnel excavation face to ensure its stability and to minimize water ingress. Based on such considerations, tunnel excavation by tunnel boring machine (TBM) using a slurry shield and having the ability to operate under high pore pressures was recommended as the method of excavation for the main running tunnels.

The paper will explain how the design team from Avrasyaconsult – the Employer's Representative – arrived at the final minimum, specific and functional requirements of the bored tunneling works which are to be carried out using the 'FIDIC EPC/Turnkey Project' conditions.

Keywords: Marmaray project; Bosphorus crossing; Closed-face shield TBM; Historical and cultural heritages; Employer's requirement

1. Outline of the Marmaray project (Fig. 1 alignment of bosphorus crossing project)

The Marmaray project is the upgrading of approximately 76 km of commuter rail from Halkali, European end, to Gebze, Asian end. It includes the new railway system that will be constructed in tunnels under the Bosphorus and it is called bosphorus crossing (BC Project), which is currently in the early stage of design and construction.

The total length of the project is 13.6 km, mainly consisting of 1.4 km of immersed tube, 10.1 km of bored tunnels, 1.3 km of cut and cover tunnels and four numbers of stations. Internal bored tunnel diameter is 7.04 m and excavated with an earth pressure balance shield coping with 2.2 km stiff clay in European side, with two numbers of slurry shield TBM coping with cracked rock 3.3 km in European side and with two numbers of slurry shield TBM coping with cracked rock 4.6 km in Asian side.

Two out of all of four stations will be constructed with cut and cover technique, one is called Yenikapi Station whose depth of track level is 17 m and the other Uskudar Station whose depth of track level is 26 m below ground. Sirkeci Station will be a tunneled type of station whose depth of track level is 45 m below ground. The remaining station is called Kazlıçeşme Station. This is a standard type of at grade station.

2. Unique characteristics of the project site environment

Istanbul is a world famous historical old city and is a mixture of influence from early Roman Empire, the Byzantium Empire, Seljuk Turkey, the Ottomans Empire and the modern state of Turkey. The bored and cut and cover

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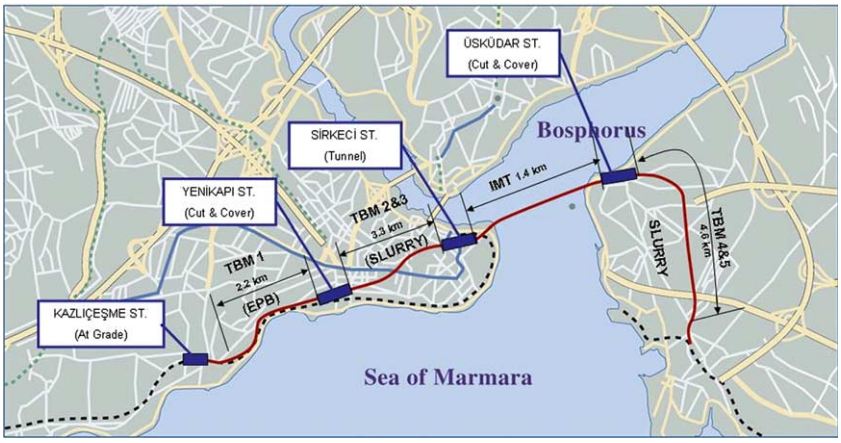

Fig. 1. Project location.

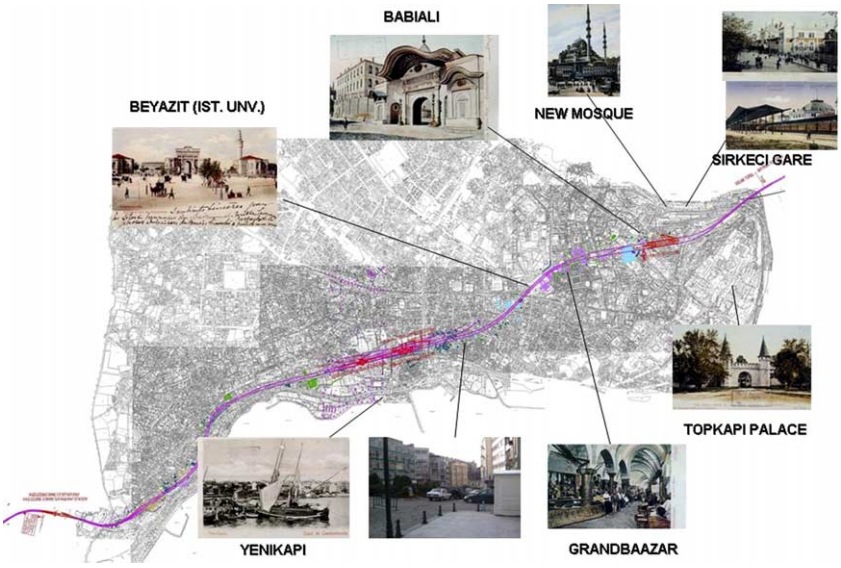

Fig. 2. The historical penninsula.

tunnels run under many historical and cultural structures and run through important archeological strata. The European side peninsula is the Historical Peninsula (refer to Fig. 2) registered as World Heritage. Urban areas are densely populated and consist of series of old 5–6 stories buildings, which are closely built to each other on the ground without positive foundations. Furthermore, there are numbers of registered or unregistered wells used for daily life. Existing TCDD line owned by the Government runs along this new line in the western part in European side and these two lines are nearly overlapped on the same plan between Yenikapi and Yedikure areas. It means the TCDD railway line which runs on the surface shall be kept operational during our tunnel construction.

3. Geology and geotechnical conditions

Fig. 3 shows a schematic composition of the geology distribution on site. Additional soil and rock investigation work has commenced from day 1 of the design and construction phase and part of the test results of the characteristics of each strata is now available.

3.1. Paleozoic sedimentary rock formations

This formation develops widely along the alignment. It consists of a sequence of alternative layers of sand silt and mudstones. In European side, mean value of maximum uni-axial compressive strength of each borehole is approximately 70 MPa and up to 120 MPa at present. In Asian side, average 90 MPa and up to 150 MPa. This formation shows cracked weak to medium strong sedimentary rocks, and cracks and joints are much developed and categorized as fractured rock mass. Lugeon values shows 1.0E − 06 to 1.0E − 8 m/s depending on joints developed.

3.2. Tertiary sedimentary formation

It consists of clayey sand containing gravels, sandy clay and stiff to hard clays with cohesion of 70 kPa

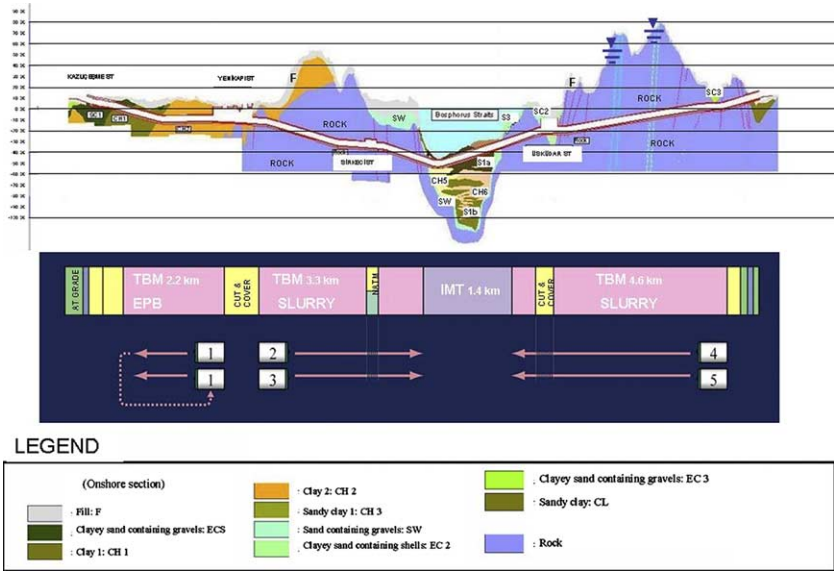

Fig. 3. Longitudinal cross-section geological profile and type of construction.

up to 250 kPa. These sediments overlie the Paleozoic rocks, and are distributed in western part of the project. Here, the tunnel runs through with shallow ground cover.

3.3. Quaternary sediments

In Sirkeci area Quaternary marine sediments distribute below Artificial fill, as sandy and silty material with shell fragments. Here, this formation overlies directly on the Paleozoic rock. Üsküdar of Asian side is located in a buried old valley. The marine deposits of sand and gravel abut the basement rock. Above the layer Artificial fill covers. The characteristics of both of these marine deposits are rather soft.

3.4. Artificial fill

It consists of clayey silty gravel with rock and brick fragments.

4. Site condition

Alignment and the method of construction have been selected due to constraints imposed, delicate site conditions and tolerable construction period. The following key points have been taken into preliminary design concept prepared by the client:

- National and World Heritages to be preserved as they are.
- Many structures and buildings are vulnerable to degradation. Therefore, tilting, differential settlement of the ground or vibration shall be minimized.
- There may be some subsurface antiquities to be protected. It is said that such antiquities may exist to the some depth from the surface.
- Limited land availability for Works Area and permanent facilities area.

You can be persuaded that in such a ciry, works area for temporary shafts or adits for tunnel excavation are absolutely limited:

- Architectural expression to be in harmony with the surrounding environment.

Numbers of exposed structures above ground, including ventilation shafts should be minimized.

- Connection with Immersed tube tunnels under the deep-sea bottom.

Location on the connection between the bored tunnel and the immersed tube tunnels might be under high water pressure, 60 m below seabed in European side and 35 m in Asian side. It requires safe and robust technique, without risk of flooding during construction:

- Time constraints of the project completion.

Rate of progress should not only be high but also steady:

- High ground water level.

Drawdown of the ground water shall be absolutely minimized.

Therefore, the preliminary design concept resulted in the following (refer to Fig. 3):

- Main running tunnels are to be excavated by TBM with shield shell.

Investment for TBM is not overburden to the project, because tunnel length is long enough:

- Closed-face shield TBM shall be used where excavation is made in any area where there is a risk of flooding from the sea.
- Non-TBM methods, including NATM may be used in limited areas, where cave, adits and other non-uniform cross-sections and junctions exist.
- Cut and cover technique is envisaged to be used for Yenikapı and Üsküdar stations.

Station needs wide space, and to be located in relatively shallow depth. Therefore, standard type of TBM has difficulties for excavation:

- Sirkeci station to be deep tunnel station.

Here, the depth of station is very deep (track level is 45 m below the ground surface) and difficult to be excavated by cut and cover technique. However, cover of rock mass above the station tunnel can be secured deep enough to use NATM with a great care and in a controlled manner:

- Cut and cover stations and station entrances shall be located to avoid existing historical heritages and residential buildings.
- Cut and cover technique can be used where enough cover is not available and bored tunneling techniques are not practical.

5. Employer's key requirements for tunnel boring machines

Excavation of main line tunnels using TBMs with shield shell is key issue for successful completion of the Project within the safety, quality, time and budget required under the Contract. Therefore, particular Employer's Requirements for tunnel boring machines have been prepared.

5.1. Preliminary design concept

- Safe personnel access into the front chamber shall be provided.

A compressed air lock is accepted:

- A minimum of two tail void seals shall be provided.
- Emergency water stops against excessive water pressure shall be provided at the inside face of the tail and the articulation joint.

It can be actuated by application of water or other hydraulic pressure:

- There shall be an Environmental monitoring system.

It can detect, levels of potentially hazardous gases, such as methane, oxygen, carbon dioxide and carbon monoxide:

- Electric power lines for main supply to move the machine and for the fire protection system shall be independent.

5.2. For settlement considerations

- For the closed-face TBM Controlled pressure on the tunnel face shall be secured.
- Continuous grouting of the tail void shall be provided.
- Ports and equipment are to be provided for probing and/or ground treatment ahead.

5.3. For flexibility consideration

- The cutter head to have a reverse rotation capability and/or to provide for over cutting.

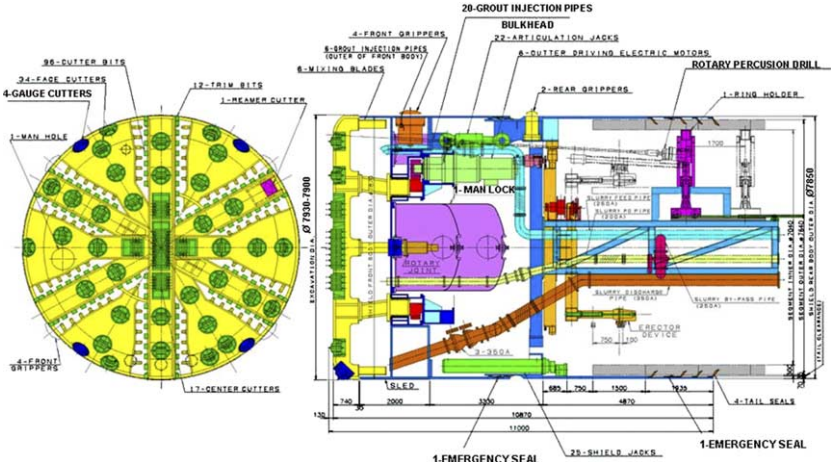

Fig. 4. Hard formation slurry shield TBM.

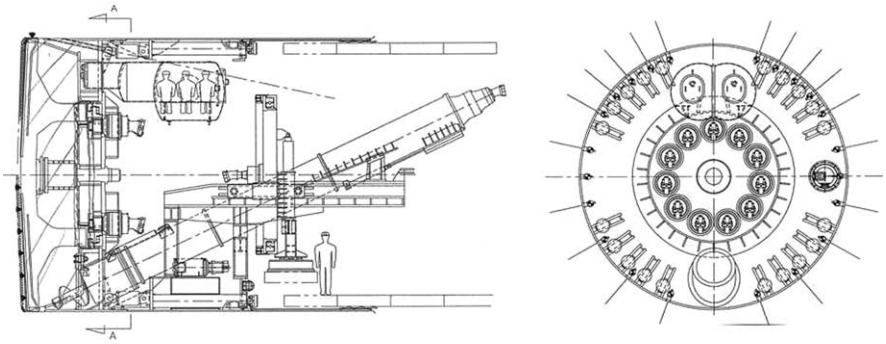

Fig. 5. Earth pressure balanced sheild TBM.

It is to enable the machine to free itself in case of blockage, which may be due to ground swelling, convergence or dilatancy of the ground.

5.4. For production considerations

- Articulation of the shield is required to negotiate curves and to correct pitch.
- Machine shall cater for various type of ground. The cutter head shall be equipped to prepare with cutters designed to cut all type of ground.
- For earth pressure balance shield it can have dual-mode operation, in open mode for hard soil but can be changed into closed mode swiftly.
- The cutters shall be replaceable from the rear of the cutter head.

6. TBM machines envisaged to be used by the Contractor

Based on the functional requirements, the type of TBMs to be used by the Contractor would be similar to (refer to Figs. 4 and 5).

- Hard formation slurry shield TBMs mainly coping with Paleozoic rock both in European and Asian side.
- Earth pressure balanced shield machines (EPBM) mainly coping with 2.2 km Tertiary formation in European side.