The Marmaray Project: Managing a Large Scale Project with Various Stake Holders

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Abstract: **This paper presents the Marmaray Project which is one of the most complex, major infrastructure projects being implemented in the world. Special challenges of the Project are explained with extra focus on Seismicity, Environmental Concerns and Historical Heritage. The stakeholders of the Project and managing the interfaces between them are discussed.**

Keywords: **Challenges, Historical Heritage, Immersed Tunnel, Marmaray Project**

I. DEFINITION

The Marmaray Project provides a full upgrading of the existing commuter rail system in Istanbul, connecting Halkalı on the European side with Gebze on the Asian side with an uninterrupted, modern, high capacity commuter rail system.

Figure 1: Alignment of the Marmaray Project

Two existing railway tracks on both sides of the Istanbul Strait will be replaced by three tracks and connected to each other with bored tunnels and an immersed tube tunnel. The entire new railway system will be 76 km long of which 13.4 km are underground (Fig. 1). The main structures and systems include the immersed tube tunnel, bored tunnels, NATM tunnels, three new underground stations, 37 surface stations, 165 bridges, 63 culverts, yards, workshops, maintenance facilities, an operations control centre, completely new electrical and mechanical systems and procurement of 440 modern rolling stock.

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II. OBJECTIVES

When introducing major infrastructure Projects such as the Marmaray Project, it is important to realise that it will influence not only the daily traffic pattern of Istanbul, but will also influence the development of the city and the region.

Figure 2: Marmaray Project, Istanbul Strait Crossing

The most important objectives are to:

a) provide a long-term solution to the current urban transport problems of Istanbul,

b) relieve existing operational problems on mainline railway services,

c) provide a direct railway connection between Asia and Europe (Fig. 2),

d) increase capacity, reliability, accessibility, punctuality and safety on the commuter rail services,

e) reduce travel time and increase comfort for a large number of commuter rail passangers,

f) provide uninterrupted passenger and freight transportation across the Istanbul Strait,

g) reduce air pollution that results from exhaust gasses, thereby improving the air quality of Istanbul,

h) reduce airborne traffic noise in the centre of Istanbul, and

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i) reduce adverse effects on historical buildings and heritage sites by offering an alternative to car transport in the historical centre of Istanbul.

III. SPECIAL CHALLENGES

The Marmaray Project offers many special challenges of which the most important ones are:
- The immersed tunnel under the Istanbul Strait will be the deepest built so far, with its deepest point some 58 m under the water surface (Fig. 3).

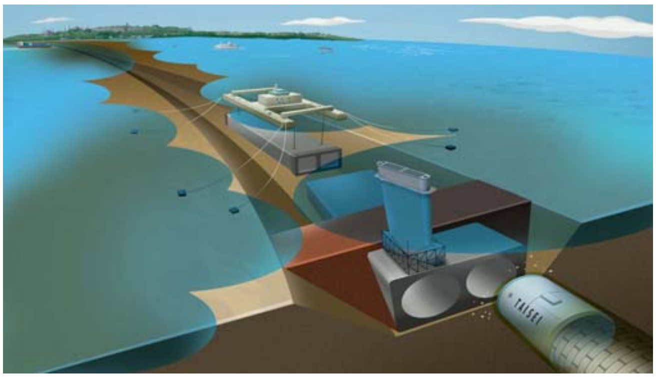

Figure 3: Illustration of the Immersed and Bored Tunnels

- The Istanbul region will most likely experience a seismic event of up to 7.5 magnitude during the lifetime of the Project.
- The geotechnical conditions of the Istanbul Strait are of such nature, that the connections between the bored tunnels and the immersed tunnel constitute a special challenge when it comes to seismic conditions.
- The ultimate capacity of the commuter system will be not less than 75,000 passengers per hour per direction. This creates special requirements for the safety of people in the tunnels and deep stations.
- The marine Works are carried out in very deep water in a water channel through which more than 50,000 ships pass every year and across which a vast number of ferries and passenger boats travel backwards and forwards.
- The immersion operations are carried out in the stratified currents of the Istanbul Strait, where the upper current velocity reaches up to 5 knots.
- The deep stations and tunnels are constructed in an area where civilization can be traced back more than 8,000 years. Therefore preservation and rescuing of Historical Heritage is a special focus point.

IV. SEISMICITY

The seismic design of the immersed tunnel was one of the most critical elements of the Marmaray Project because of the tunnel's proximity to the seismic fault system which is only 16 km away.

For the Marmaray Project the minimum seismic design requirements are based on a single-level design earthquake defined as the design basis earthquake (DBE). Both probabilistic and deterministic approaches were used for assesing the seismic hazards.

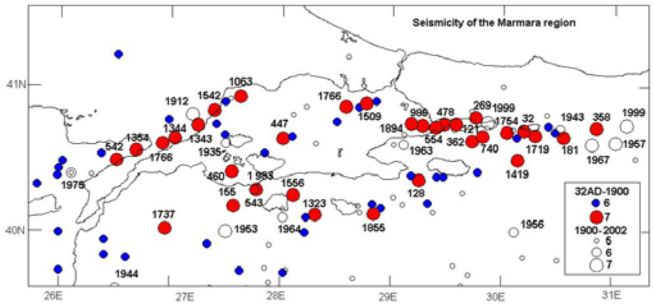

Figure 4: Seismicity of the Marmara Region, M>7.0 Erthquakes

A number of M>7.0 earthquakes have occurred in the Marmara Region since 1500 (Fig. 4). After detailed assesment of the distribution of reported eartquake damages, these major historical earthquakes were correlated to the fault segmentation model presented in Fig. 5. A Mw=7.5 (moment magnitude) earthquake was selected as the maximum credible earthquake scenario for this Project and assumed to take place on Segments S5 through to S8 along the main North Anatolian Fault Zone.

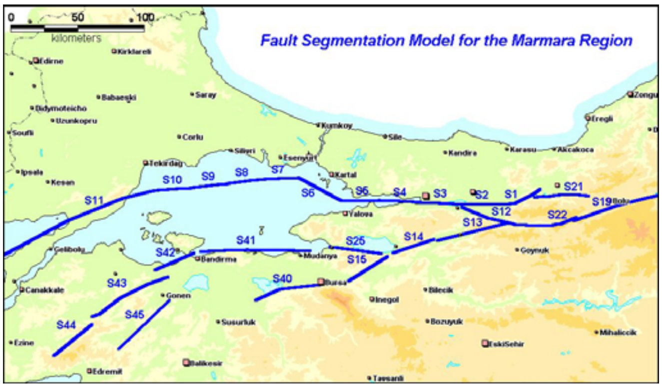

Figure 5: Fault Segmentation Model for the Marmara Region

The minimum performance requirements of the tunnel structures were such that when subjected to DBE:
- damage should be repaired easily and would not result in a loss of function or lives;
- the tunnel would remain watertight;
- the facility would remain operational following the earthquake and require not more than a few days for inspection and adjustment of the rail alignment;
- repair work could be performed with minimum disruption to the operation of the facility.

Figure 6: Compaction Grouting Works in the Istanbul Strait

Due to the existence of loose sand along 470 m of the immersed tunnel alignment, liquefaction and liquefaction-induced ground deformations have also been taken into consideration in the immersed tunnel design.

The potentially liquefiable area was improved by compaction grouting. This work (Fig. 6) involved injecting 2778 cement grout columns into the ground on a 1.7 m grid up to the subgrade elevation of the tunnel. The effectiveness of the compaction grouting treatment was verified by cone penetration tests (CPT) which provided data on the post-treatment liquefaction settlement values.

V. ENVIRONMENTAL CONSIDERATIONS

Istanbul is a fast growing city with an increase in population in the order of 300,000 per year. This automatically creates an increase in the demand for transportation of people every year. Furthermore, Istanbul is a city that has fast growing and deepening problems with its transport infrastructure. There is severe traffic congestion in the morning and evening rush hours, the rush hours are expanding and the options for increasing the general capacity of the road system are becoming fewer.

The peak hour capacity of the Marmaray Project will be 75,000 passengers per direction. It will have common transfer stations for transfer tı abd frın the existing and planned railway systems of the Metropolitan Municipality of Istanbul. It has been calculated that the following reductions in the amount of pollutants and greenhouse gasses will be achieved by the Marmaray Project:

i) Air pollution gasses (NMHC, CO, NOx etc.): In the opening year 2012 there will be a reduction of minimum 15,000 tons, with this figure rising to 25,000 tons by the year 2025.

ii) Greenhouse gasses – mainly CO2: In the commencement year there will be a reduction of minimum 225,000 tons, this figure rising to 400,000 tons by the year 2025.

The Marmaray Project connects two continents by a railway under the sea. The operations in the sea set this project apart from other railway projects. During these operations sustainability of environmental protection was also a major consideration.

Figure 7: Dredging in the Istanbul Strait

A total of 1,300,000 m3 dredging has been carried out in the Istanbul Strait. Initially some 120,000 m3 of contaminated soil were removed from the upper 3 metres near the outlet of the Golden Horn estuary on the European side (Fig. 7). This material was barged and trucked to a confined disposal site some 30 km East of the tunnel site. In accordance with Turkish and International laws and regulations a confined disposal site with a capacity of 250,000 m3 was prepared specially for this project.

The remaining dredged material was barged to a sea disposal area, the Çınarcık Ditch, 16 km South of the project alignment in the Marmaray Sea. It is located in the North Anatolian Fault Zone and has a depth of 1,200 m, whereas the average depth in the Marmara sea is around 200 m. The water quality at the disposal site before, during and after the disposal activities were monitored at three different depths and in 4 monitoring stations.

Another important issue that was considered during the dredging was the fish migration through the Istanbul Strait. The length and start of the two fish migration periods per year varies for each type of fish. However, it is generally accepted that the spring migration lasts from 15 March to 15 June, and the autumn migration from 5 September to 15 November. The flow in the Istanbul Strait is a strong, stratified two-layer system. The spring migration takes place from the Marmara Sea towards the Black Sea, in the lower saline layers that flow in the northern direction. The autumn migration takes place in the opposite direction in the upper non-saline layers that flow towards the south, or in the neutral zone between the upper and lower current. Turbidity of the water during the fish migration period was the potential main problem. Fortunately, the currents in the Istanbul Strait are quite constant and always present. Therefore, the spill from the dredging concentrated in well-defined and narrow areas and the fine debris was carried to the natural sedimentation areas in the Marmara Sea and in the Black Sea (Fig. 8).

Figure 8: Turbidity plume due to dredging in the Istanbul Strait

Another potential main problem was the possible noise impact created by the dredger. It is known that fish interpret continued noise as a barrier which they are reluctant to approach. During the fish migration periods “Feedback Monitoring” was carried out by the university. This concept enables a quicker and more effective assessment and allows adjustments to be made to the ongoing construction activities. The variables monitored were surface temperature values and seawater temperature profiles, the concentration of suspended soil at a certain distance from the dredger and the real-time landing data of migrant fish in the fishing ports

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at both ends od Istanbul Strait. Based on this feedback data it was possible to take more precise decisions regarding the continuation of the marine works.

VI. HISTORICAL HERITAGE

Istanbul was the capital of three Empires, the Otoman, Byzantine and East Roman Empire. In Sirkeci, during the construction of a 25 m diameter shaft, a 13 m cultural fill layer was excavated by archaeologists (Figure 9). In the upper layers architectural findings from the Ottoman period were encountered. The subsequent layer contained structures and small artefacts from the Byzantine period. Then Roman architecture and artefacts were unearthed. The last 3 m took 6 months for the archaeologists to excavate, understand and remove. This layer belonged to the colonial period of Istanbul.

Figure 9: Sirkeci West Shaft Archaeological Excavations

During the archaeological excavations in Yenikapı, the antique Theodosius harbour was excavated. This harbour was built in 3rd century A.C. and until the 11th century A.C.

27 ships were uncovered so far during the excavations (Fig. 10). Amongst these are commercial ships of varying sizes, small fishing boats and boats with long oars. After the measurement surveys and documentation work is done, the ships are transferred by experts to special pools where for a period of 5 years they undergo conservation work. Following this treatment they are ready to be exhibited.

Figure 10: Shipreck from 11th century A.C. in Yenikapi

Naval power was very important to Byzantine. The ships uncovered provide valuable information on the design and construction methods of Byzantine ships, their load-baring capacity and the conditions under which they operated. The research undertaken by the experts will reveal information, unequalled in importance, on Byzantine fleet ships and the constructions methods used in the Middle Ages.

The findings uncovered during the archaeological excavations in the Uskudar station area are very significant, particularly with regard to the Byzantine history of Uskudar.

The remains of foundations of an apsidal structure uncovered during these excavations show that this location is no longer part of the original bay that was filled in at a later stage, but that we are now on original land. The plan and materials of the structure believed to be the foundation of a religious building, can be dated back to 12-13 century A.C.

The discovery of the Temenos wall outside the square-planned structure makes it all the more interesting. This religious building must have been a church or a chapel or a Martyrion. It must be noted that the axis of the building does not lie exactly in a east-west direction. More than 25 skeletons were found inside the building and between the building and the Temenos wall. These were documented and sent to Ankara University, DTC Faculty Antropology department for investigation (Fig. 11). In some places the walls are constructed on top of the knees of some of the skeletons but the skeletons remained whole, which shows that the apsidal structure was built at a later date than the burial.

Figure 11: Skeletons in the Religious Building in Uskudar

VII. ORGANISATION AND MANAGEMENT

The responsible directorate for the implementation of the Project and for reporting to the Ministry of Transport is the General Directorate of Railways, Harbours and Airports Construction, the DLH.

The organisation responsible for the Engineering and Consulting Services for the Project was selected via competitive bidding. Avrasyaconsult was the successful bidder. This organisation is now the Employer's Representative on the construction sites and reports to DLH.

Avrasyaconsult is an international team that consists of four partners from Turkey and Japan, and receives assistance from international consultants from the USA and local consultants from Turkey.

The Project is managed under three seperate contract packages: the Bosphorus Crossing Contract (BC1), the Commuter Rail Infrastructure and Systems Contract (CR1) and the Rolling Stock Contract (CR2). The FIDIC Conditions of Contract for EPC/Turnkey Projects is used in all three contract packages. Unless stated otherwise in the Employer's Requirements or the Particular Conditions of Contract, this set of general conditions allocates most risks related to unforseeable conditions to the Contractor and acts as an extensive risk sharing mechanism. The main principle is, that the party who is best able to control or mitigate a risk, must also accept responsibility for that risk. Therefore the Contractor had to include these risks in his bidding price, in other words, the Employer paid for the risks in advance.

VIII. PARTIES INVOLVED IN VARIOUS STAGES

In the Marmaray Project there are various stake holders who are involved in different phases of the project. Management of all the interfaces creates special challenges for the Project.

The Marmaray Project is co-financed by three financing organizations. These are the Japan Bank for International Cooperation (JBIC), the European Investment Bank (EIB) and the Counsel of European Development Bank (CEB). Each organisation has their own guidelines which the borrower has to follow during the tender stage. They also require periodical reporting in their format throughout project implementation.

The Contractor of the BC1 Contract is the Taisei-Gama-Nurol Joint Venture, which consists of Taisei from Japan and the companies Gama and Nurol from Turkey. The Contractor of the CR1 Contract is the Alstom-Marubeni-Dogus Consortium, consisting of Alstom from France, Marubeni from Japan and Dogus from Turkey. The CR2 Contract is in the tender stage and has not yet been awarded.

Many experts and engineers from various countries are involved in this intercontinental project. All the staff from various different racial, cultural and religious backgrounds, have devoted themselves to the project and work together towards a successful completion.

The Marmaray Project starts from Gebze on the Asian side and ends at Halkali on the European side. Along this 76 km long corridor the Project passes through two cities and 10 different municipalities. Each municipality has their own vision and priorities for their territory. A common request from municipalities was that the Project crosses their district underground, leaving the surface free. As this request is against the feasibility conditions of the project, it had to be rejected each time.

The Marmaray Project is designed to be the backbone of the transport system in Istanbul. It is going to be fed by the various transport facilities of the municipalities. The contractors of the municipalities and the Marmaray contractors have to work in the same work area to build shared transfer stations. To minimize possible time delays due to interfaces between these parties forms a focus point for the Employer.

Figure 12: Sea traffic in the construction area

The marine works of the Marmaray Project are carried out in a densely navigated area (Fig. 12). There is international transit traffic as well as local traffic between the two sides of the Istanbul Strait. The width of the existing two directional navigation channel was reduced and during the marine works only traffic in a single direction was permitted.

In the Contract documents the full-time presence of a Pilot Captain on Contractor's vessels that work in the Istanbul Strait, is stipulated. Since the Contractor's vessels were anchored and stationary, the Pilot Captains were used to instruct particularly the transit vessels in order to prevent possible collisions. The Marine authorities, pilot captains and especially the Harbour Master played an important role in the smooth running of the marine works in the project.

UNESCO declared Istanbul a World Cultural Heritage site. Furthermore, Istanbul is nominated as the European Capital of Culture for the year 2010. UNESCO delegations visit the project regularly and advice on the impact of the Marmaray Project on the cultural heritage of Istanbul and also monitor the implementation of the project. UNESCO's involvement in advising the Project Management is both an international duty entrusted to the Organization by the international community and also a sense of responsibility towards the World Heritage Convention.

IX. CONCLUSIONS

Construction in a densely populated urban environment is always difficult. It is especially so with the Marmaray Project because of the great number of stake holders involved and also because of Istanbul's unique history and nature.

The Marmaray project is desperately needed to ease the traffic congestion in a metropolis of 13 million inhabitants. Meeting the needs of today and tomorrow without compromising the past or nature involves special challenges.

The Marmaray project is a large scale project with interfaces with various stake holders and third parties - a situation which brings with it a real risk of delays and cost increases, and forms one of the major challenges in the project.