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Long-Span Orthotropic Steel Deck Bridges of Turkey

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Abstract. Long-span bridges are the key structures for transportation systems and they are considerably needed in Turkey since it is a transit country between Europe and Asia Continents. Besides, Turkey has many large reservoir dams, so these kinds of bridges are essential to provide transportation. Long-span orthotropic steel deck bridges are the main and the most important links in the transportation network of the country. This study presents the general features of the long-span orthotropic steel deck bridges in Turkey, namely The July 15 (the 1st Bosphorus) Martyrs Bridge, the Fatih Sultan Mehmet Bridge (the 2nd Bosphorus Bridge), the Yavuz Sultan Selim Bridge (the 3rd Bosphorus Bridge), the Osman Gazi (İzmit Bay) Bridge and the Canakkale 1915 (Dardanelles) Bridge. The importance behind the selection of long-span bridges in Turkey is explained and detailed information for recently ongoing project of the Canakkale 1915 Bridge is given. The outcomes from the current study are aimed to provide important vision for the construction of new long-span bridges in the world.

1. Introduction

Of all the civil infrastructures, long-span cable-supported bridges are the lifeline structures for the transportation network in a country/state. These bridges are not only a substantial component in transportation system, but also offer a respectable contribution to economic and cultural growth of their regions [1].

Transportation infrastructures play a critical role in Istanbul and Marmara Region, Turkey. İstanbul is located approximately in the middle of the Marmara Region and the city links between two continents of Asia and Europe. As a result of the increase in population and consequently in traffic of Marmara Region (25% of total population of Turkey), the importance of long-span bridges raises significantly and rapidly in Turkey. More specially, the city of İstanbul with a population of 18 million has a strategic position holding three Bosphorus Bridges and being close to the Osman Gazi and Canakkale 1915 Bridges.

Along with the existing 1st and 2nd Bosphorus Bridges (the Fatih Sultan Mehmet), numerous efforts have been continuously made to meet all needs for the transportation service with the newly completed long-span bridge projects of the 3rd Bosphorus Bridge (the Yavuz Sultan Selim Bridge) and the Osman Gazi Bridge located on Izmit Bay relatively close to Istanbul. The Osman Gazi Bridge is one of the bridges that were opened to traffic in the soonest time, in July 2016. The bridge, a 2.682-meter long-structure, is said to be the 4th longest suspension bridge in the world and the 2nd longest in



Europe. The importance of this structure is to ensure the integrity of transport between the two sides of İzmit Bay, the country's western provinces and consequently reducing travel time between İstanbul. With this project, the average travel time between İzmir (a province of the Aegean region) and İstanbul was reduced from ten hours to approximately four hours [2, 3].

It was decided to construct the Canakkale 1915 Bridge (named in memory of Turkey's historic victory in the region during World War I) with the idea of connecting Thrace to the Aegean and the Western Mediterranean via Canakkale. Upon completing this project, the bridge will have been the longest (32 meters longer than the world's longest bridge, the Akashi-Kaikyo Bridge) bridge between two shores in the world. Besides, a significant support will be provided to solve the traffic problem in İstanbul, especially on the Bosphorus Bridges. It will be the 5th suspension bridge in the sea of Marmara Region, will contain six traffic lanes, three in each direction and will reduce the Canakkale crossing time from 45 minutes to 4 minutes. The bridge will be built on approximately 200 kilometers away from the southwest of İstanbul and it is expected to open in 2022. The locations of the bridges on the Turkey Map are shown in Figure 1.

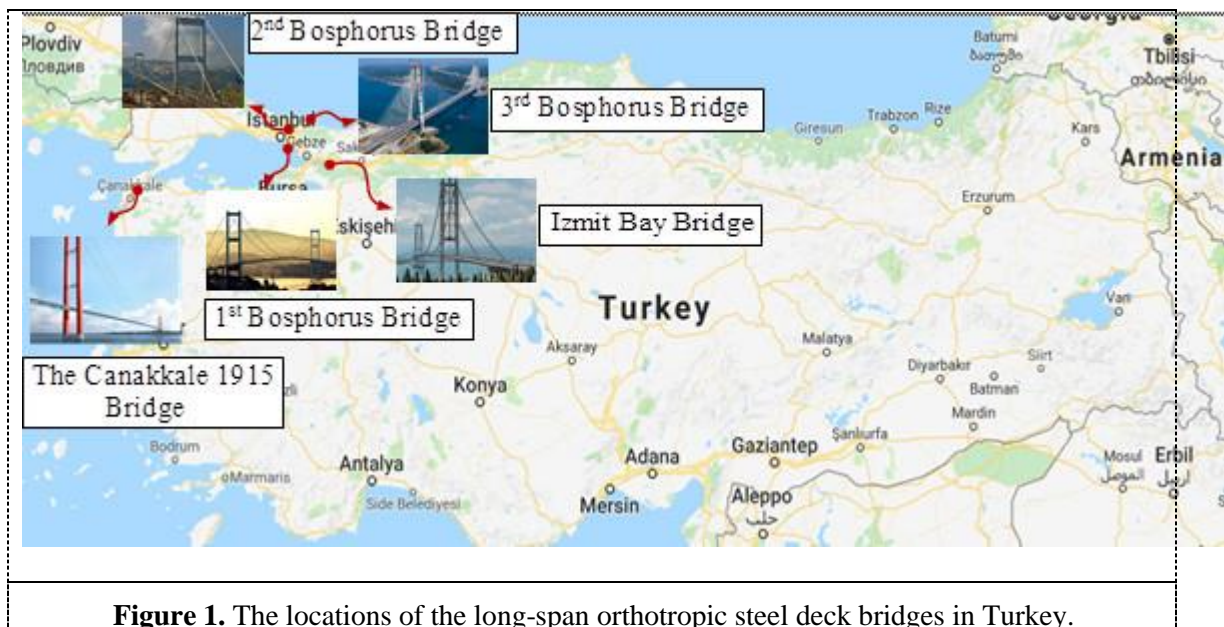


Figure 1. The locations of the long-span orthotropic steel deck bridges in Turkey.

2. The First Bosphorus (15th July Martyrs) Bridge

The history of bridge projects on the Bosphorus Straits dates back ancient times, to 522 BC - 485 AC. However, the first decision to build a long-span bridge over the Bosphorus River was in 1957. The British firm Freeman Fox & Partners designed the bridge in 1968. After its construction started in 1970, the bridge was commissioned in 1973 corresponding to the 50th anniversary of the Republic of Turkey. With its main span, the bridge was the longest suspension bridge in Europe until the completion of the Humber Bridge in 1981. It was also the 4th longest bridge in the world upon completion in 1973. The First Bosphorus Bridge is a steel suspension bridge with three standard traffic lanes. Its structural type and design considerations are mostly similar to that of the Humber and Severn Bridges, which are the first modern bridges in Europe with the aerodynamic box deck section [3, 4].

The First Bosphorus Bridge is a key civil infrastructure in transportation networks of İstanbul, with one of the beltways between the two continents designed after the construction of the bridge. Therefore, the bridge currently serves as significant link for the city of İstanbul. As indicated in Figure 2, the First Bosphorus Bridge is a gravity-anchored type of long-span steel suspension bridge. The aerodynamic box deck section and the towers with tapered box section are the key indicators of a modern bridge. The bridge has the main span length of 1074 m and two approach-spans with the length of 231 m at the European side and 255 m at the Asian side, respectively. Only the main span is

suspended with the suspenders; nevertheless, the approach spans are supported at the base instead of the suspender elements. The width of the deck is 33.40 m and its height is approximately 3.00 m [3].

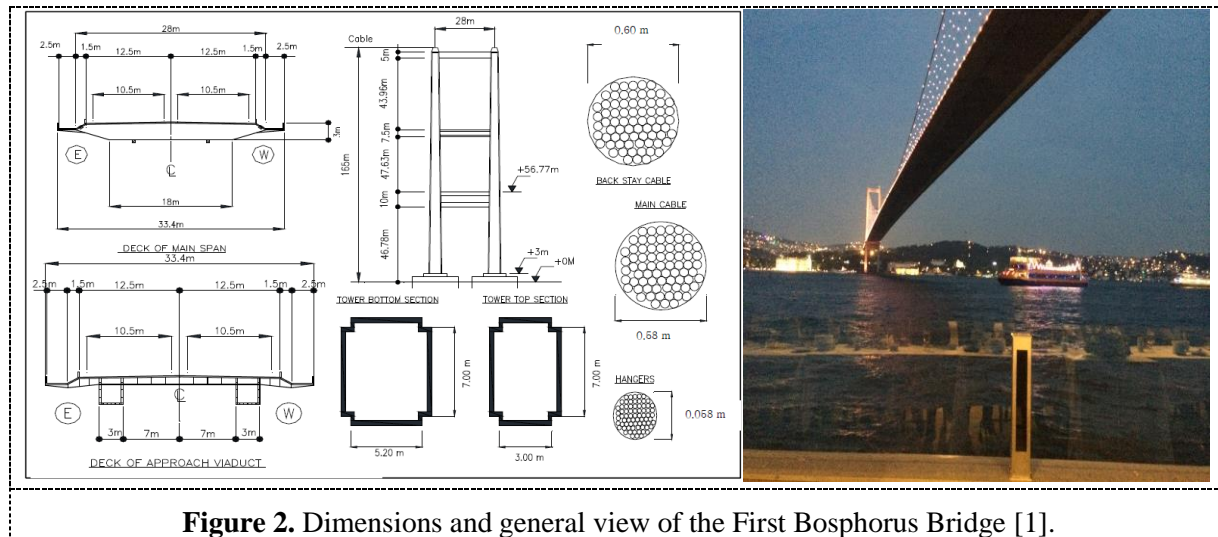


Figure 2. Dimensions and general view of the First Bosphorus Bridge [1].

3. The Second Bosphorus Bridge (The Fatih Sultan Mehmet Bridge-FSM)

Based on the decision on new beltway (O-2) in Istanbul called Trans-European Motorway (TEM), constructing the 2nd Bosphorus bridge was inevitable. Accordingly, the British firm Freeman Fox & Partners prepared the second project for the long-span bridge over the Bosphorus Strait. The construction was started in 1986 and the bridge was completed in 1988 in which the bridge was the 5th longest suspension bridge in the world; it is now ranked 21st. The Second Bosphorus Bridge located on the north side of the First Bosphorus Bridge was named the Fatih Sultan Mehmet Bridge (FSM) [5, 6].

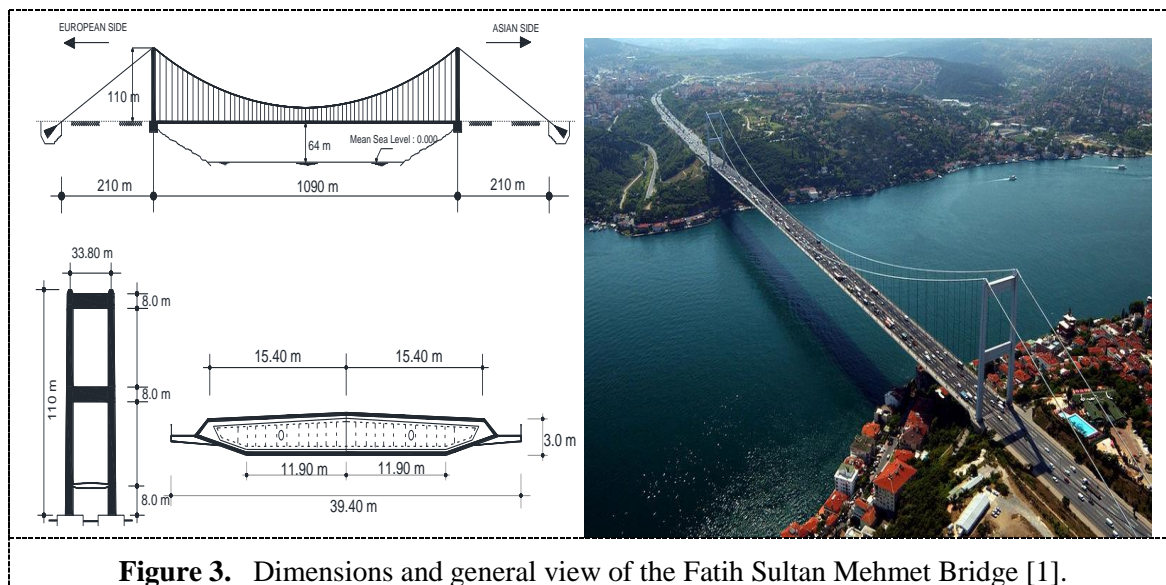


Figure 3. Dimensions and general view of the Fatih Sultan Mehmet Bridge [1].

As shown in Figure 3, the Fatih Sultan Mehmet Bridge is a steel long-span suspension bridge. The towers of the bridge are supported at the ground level, which means that the ends of the deck are the level of the tower base. Therefore, the bridge has no approach span. The main span length of the bridge is 1090 m and the deck with aerodynamic box section has a width and height of 39.40 m and 3.00 m, respectively. The tower of the bridge is a rectangular box section and the total height of the

tower is 110 m. The deck of bridge at the mid-span is 64 m high from the mean sea level. With the side span length of 210 m at the two continents, total length of the bridge is 1510 m. Since the TEM highway is the only route allowed for truck and other heavy vehicles, the bridge is subjected to various heavy traffic loads [6].

4. The Third Bosphorus Bridge (The Yavuz Sultan Selim Bridge-YSS)

The construction of the Third Bosphorus Bridge was started in 2013 and it was finished within three years. The Third Bosphorus Bridge called the Yavuz Sultan Selim Bridge, which is a hybrid cable-stayed-suspension structural system, is located at the entrance of the Bosphorus River to the Black Sea, which is approximately 5.0 km north from the First Bosphorus Bridge. With the 322 m height of tower and approximately 59 m width of the deck, it is the widest and the second tallest suspension bridge in the world. The YSS Bridge is designed not only as a motorway with four lanes but also as a railway with one lane in each direction. Therefore, the bridge is the world's longest suspension bridge with railway system. As indicated in Figure 4, the main span length of the bridge is 1408 m and total length is 2164 m. The towers with triangular hollow section are designed as reinforced concrete, but the other elements are made of structural steel [1].

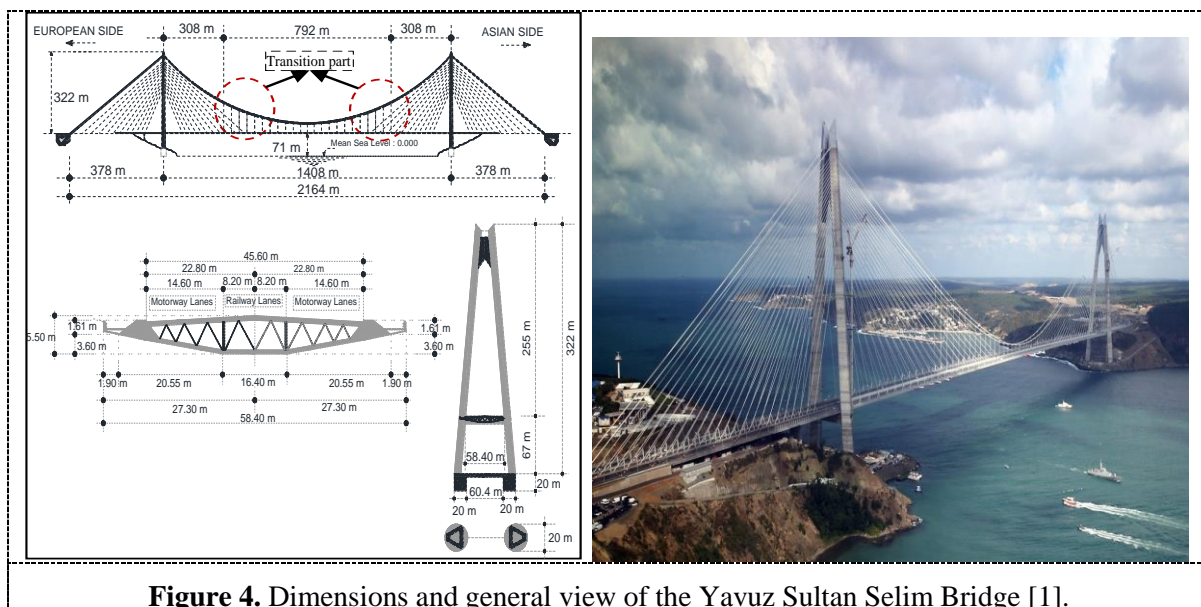


Figure 4. Dimensions and general view of the Yavuz Sultan Selim Bridge [1].

5. The Izmit Bay Bridge (The Osman Gazi Bridge-OGB)

Other than the Bosphorus Bridges in Istanbul, the first long-span suspension bridge is constructed for the Izmit Bay at the eastern side of the Marmara Sea, very close to the city of Istanbul. The long-span suspension bridge is planned as a significant link for the Istanbul-Izmir Motorway to considerably reduce the distance between two cities. The construction of the Osman Gazi Bridge was started in 2013 under the build-operate-transfer contract, and the bridge was opened to traffic in 2016. According to the main span length of 1550 m, the bridge is the fourth longest suspension bridge in the world.

General arrangement of the bridge is shown in Figure 5. The bridge has three spans: two approach spans with the length of 566 m and one main span. However, there is also transition span with the length of 120 m at the anchorage blocks at each side of the bridge. Accordingly, the total span length of the bridge is 2907 m. The height of the tower with box section is 252 m and towers are supported by concrete foundations submerged into the sea. The main deck with the width of 30.10 m and the height of 4.75 m was designed for the three standard traffic lanes in each side. The deck has also aerodynamic box section braced by the internal truss elements and diaphragm [1].

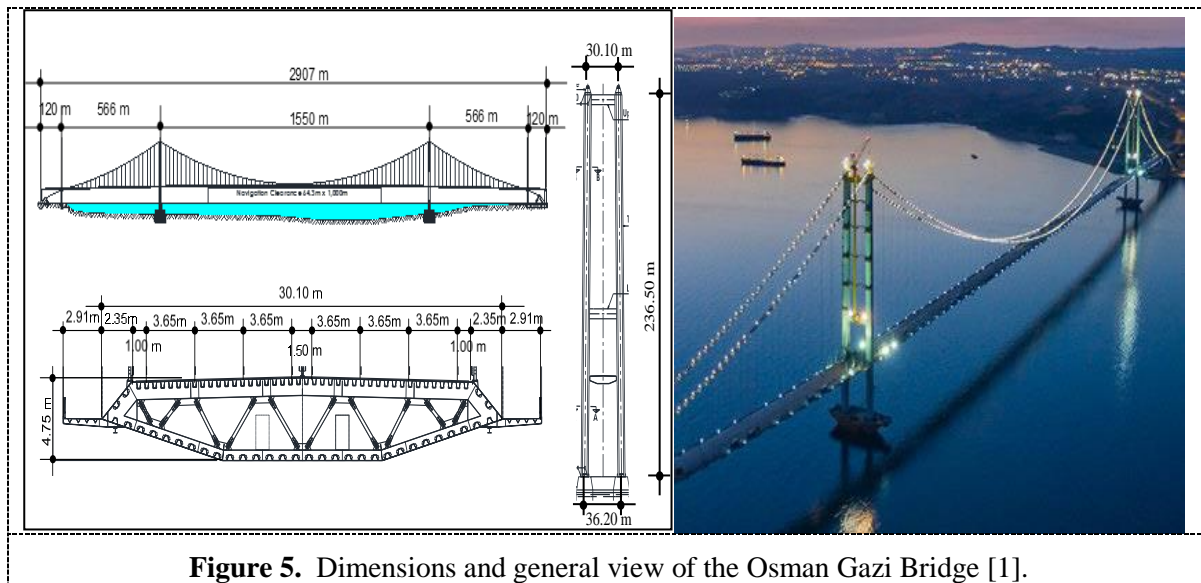


Figure 5. Dimensions and general view of the Osman Gazi Bridge [1].

6. The Canakkale 1915 (Dardanelles) Bridge

Another important link to Istanbul and the Marmara region where the majority of the population of Turkey is concentrated is the Canakkale Straits. Due to this crucial geographic location of the Canakkale, it was decided to construct the Canakkale 1915 Bridge (named in memory of Turkey's historic victory in the region during World War I) with the idea of connecting Thrace to the Aegean and the Western Mediterranean via Canakkale.

As shown in Figure 6, the bridge is connected with a new highway project of Malkara-Canakkale to be completed at the same time with the Canakkale 1915 Bridge. This highway project is planned to make a connection of Istanbul to Canakkale and Northern Aegean location. This new connection including the suspension bridge project also provides an effective solution to link to many harbors, railways and air transportation systems between Aegean and Marmara regions that are the most important locations of Turkey. Besides, general dimensions of the bridge in plan are summarized in Figure 6 with the main span length of 2023 m and the side span length of 770 m [7].

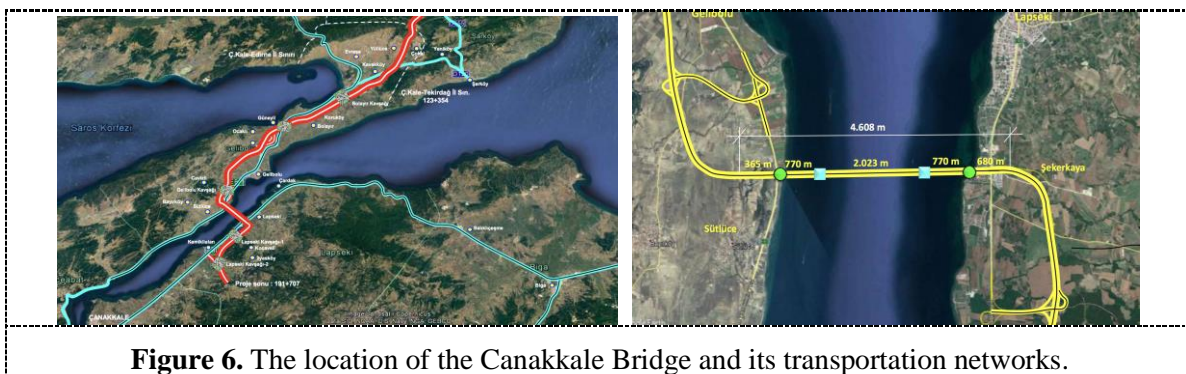


Figure 6. The location of the Canakkale Bridge and its transportation networks.

The bridge has a tapered rectangular hollow section towers with a total height of 318 m from the sea level. The tower foos are casted on the sea bottom at 40 m below from the sea level. As depicted in Figure 7, dimensions of the base and top tower sections are 11.00m x 10.50m and 8.00m x 7.50m, respectively. The main span deck has an orthotropic steel deck with the height of 3.50 m and the width of 45.06 m. Three lanes are considered for each direction. The side span of the bridge also follows the approach viaduct supported at the base for each side as indicated in Figure 7. With these properties, the bridge is will be the longest suspension bridge in the world upon constructed as revealed in Figure 8.

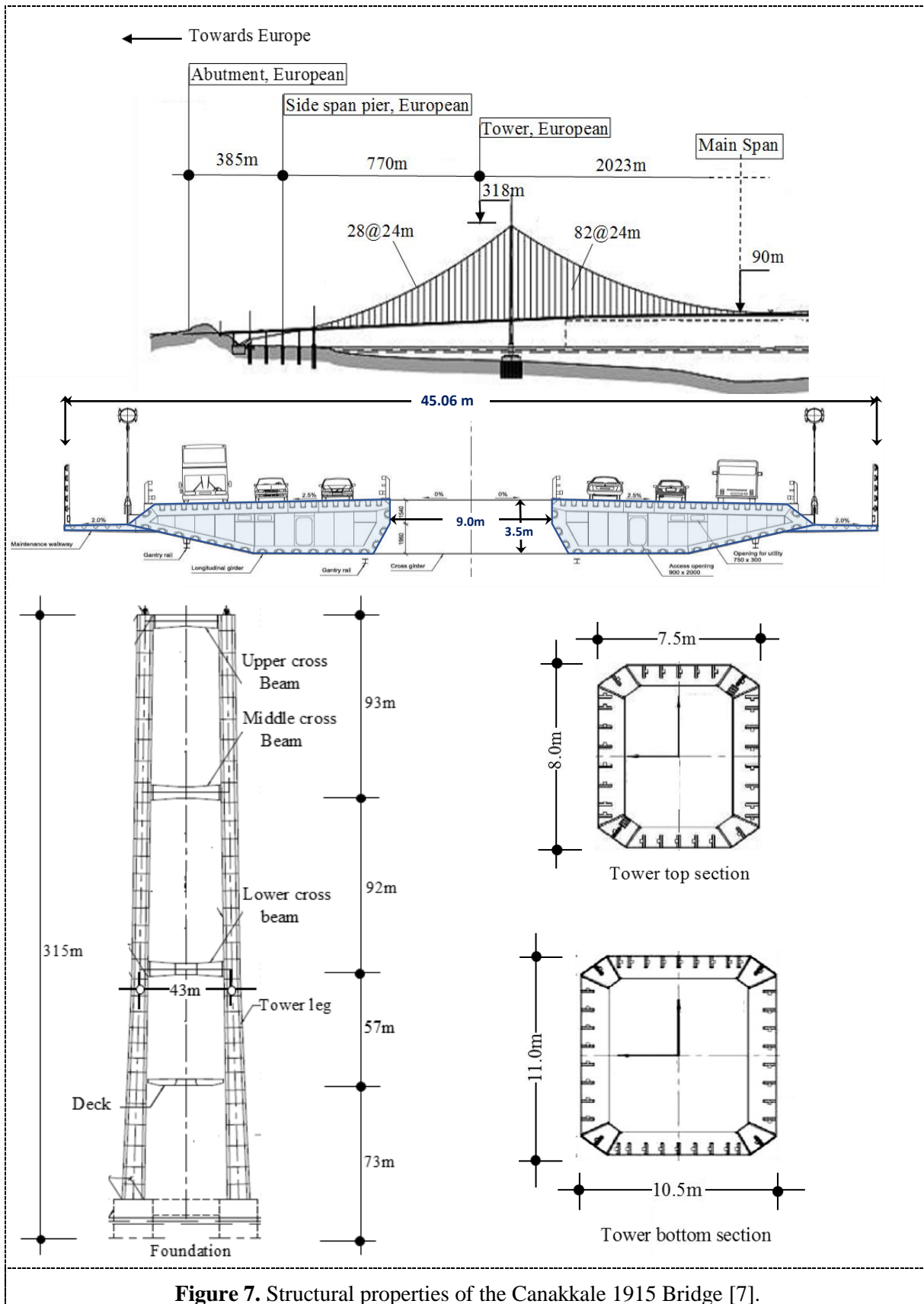


Figure 7. Structural properties of the Canakkale 1915 Bridge [7].

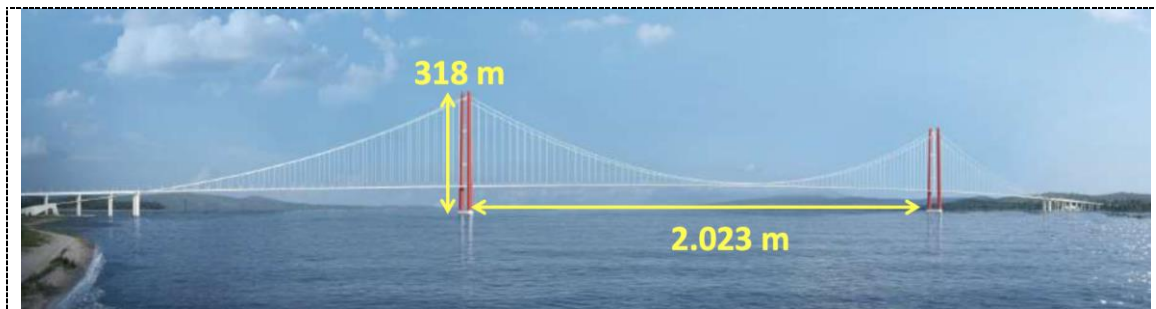


Figure 8. General view from the completed version of the Canakkale 1915 Bridge.

7. Conclusions

The most important regions of Turkey, Aegean and Marmara Regions, have a natural straits and rivers more suitable to build landmark civil infrastructures. With the rapid increase in the population of these regions, the need for the long-span bridges that provide critical connections is indispensable to establish effective transportation networks in Turkey. Due to these properties of Turkey, long-span orthotropic steel bridges are the key infrastructures in its transportation system. In this paper, general structural properties of the existing long-span orthotropic suspension bridges, the 1st Bosphorus (15 July Martyrs), the 2nd Bosphorus Bridge (the Fatih Sultan Mehmet), the 3rd Bosphorus Bridge (the Yavuz Sultan Selim) and the Osman Gazi Bridge, and the ongoing bridge project of the Canakkale 1915 (Dardanelles) Bridge are presented. Based on the critical properties of the bridges, the following points are underlined,

- Considering certain challenges and disadvantages during the construction of 1st and the 2nd bridges, the new completed Yavuz Sultan Selim Bridge (YSS) and Osman Gazi Bridge (OGB) effectively designed, which means that maintenance, management and safety requirements are estimated appropriately in the bridge.
- The outputs and experiences obtained from the new bridge project of the YSS and OGB provide an opportunity to specifically determine project considerations of the Canakkale 1915 Bridge and to make an effective solution to design and construction processes of the bridges.
- The experiences from the long-span orthotropic steel deck bridge projects indicate that Turkey is one of the best example of implementing landmark civil infrastructures projects and thus have a number of experiences for both project and construction works.
- With the last bridge project of the Canakkale 1915 Bridge, the longest suspension bridge with orthotropic steel deck in the world according to its main span length of 2023 m will be constructed on the Dardanelles River.

Considering these important conclusions on the long-span orthotropic steel deck bridges in Turkey, it is clear that civil infrastructure technologies and resilience considerations should be developed for the effective post design strategies of maintenance, management, safety and life extension of these bridges.

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