International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 03, March-2019

COMPREHENSIVE STUDY ON TECHNIQUES DEVELOPED TO OVERCOME CONSTRUCTION CHALLENGES OF AKASHI KAIKYO BRIDGE

Arsalan Farooq

Assistant Professor, Department of Civil Engineering, IUST Awantipora

Abstract: The Akashi Kaikyo Bridge is the largest suspension bridge in the world. It is situated on the Akashi Strait. The width of the strait at the proposed site is 4 km and the depth of water is 110 m. The maximum tidal current has velocity of 4 m/s and the maximum wave height is 9.4 m. The basic wind speed for design is 46 m/s. The site is also prone to earthquake. As such the construction of bridge on such location was very difficult task. The engineers incorporated various innovative techniques to overcome these challenges. The paper presents in detail knowledge about the construction of tower foundation and towers, fixing of steel cables and placing of roadways.

Keywords: tuned mass damper; laying down caisson; cables; aerodynamic stability, precast concrete panel.

1. Introduction:

It is also known as Pearl Bridge and is the largest suspension bridge in the world. The towers measure 280m above MSL. They are as tall as Eiffel Towers. It is situated on Akashi Strait which is one of the world's busiest shipping lanes with 1000 ships plying through it daily. It connects Maiko in Kobe and Lwaya on Awaji Island. The project was started in 1988 and finished in 1998. For construction purpose 1.4 million cubic meters of concrete and 181000 tons of steel was used. Over 2 million workers were used for construction. The total cost of construction is $4.3 Billion, making it the most expensive bridge in the world.

Fig 1: Image of bridge taken by NASA's spacecraft Terra

2. Stages of construction:

The Akashi-Kaikyo bridge was constructed in 4 phases:
Phase 1: - Construction of Tower Foundation
Phase 2: - Construction of Towers.
Phase 3: Attaching of Steel Cable with the Towers
Phase 4: - Placing the Roadway.

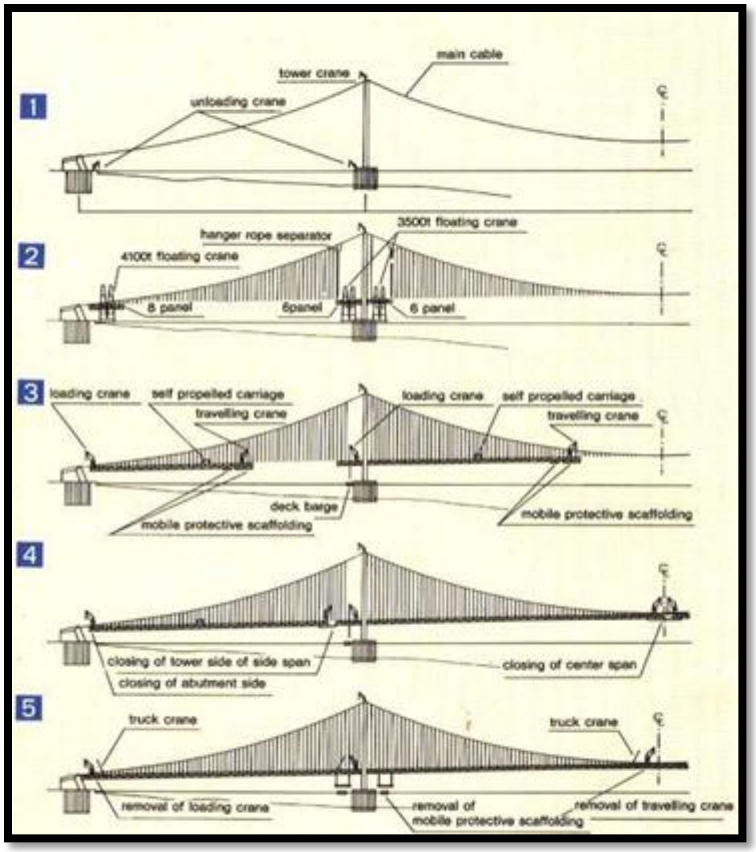


Fig 2: Stages of Construction

6.1 Challenges for Construction of Tower Foundation:

For construction of Tower foundation, the design parameters taken into consideration were depth of water at main pier site (45m), maximum velocity of tides (4 m/s) and maximum height of wave (9.4 m). The two main piers have circular plane shape and Laying down caisson method was used for construction of these piers. An improved excavation method and underwater concreting method were used. On the other hand, the caisson had a possibility to overturn from scouring due to the accelerated flow and horse shoe vortexes which were generated by presence of the caisson itself. For protection against the scouring filter units and cobble stones laid on them were placed.

Fig 3: Protection of the Caisson against Scouring

Two enormous steel moulds were built in the dry docks and were then towed to sea and sunk at the precise location. The steel moulds were 70m tall, 80m wide and weighed about15000 tons. The moulds were sunk by filling with seawater. After sinking the mould next challenge was to fill the mould with concrete. As the mould contained sea water it became difficult to set concrete. To overcome this problem engineers invented a super-concrete that would easily set in seawater.

Fig 4: Sinking Of Caisson

6.2 Challenges for Construction Of Towers:

The towers had to withstand not only the self-weight but also the load due to earthquake (nearest epicenter being 150 km away) and Wind. So, the towers were built of Steel. They were built of 90 blocks. As per the survey a minimum data of 1500 m was to be provided for waterway. After taking topographical and geographical factors into consideration the length of main span was taken as 1900 m. Towers measure 280m above MSL. They are as tall as Eiffel Towers.

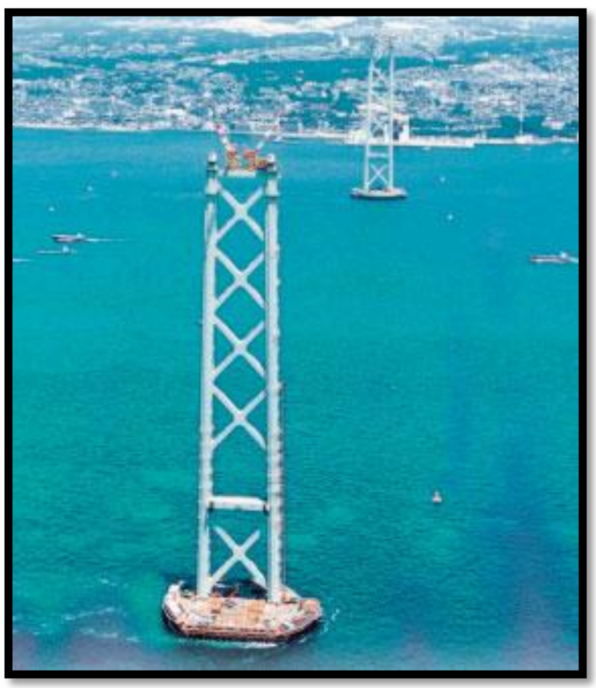


Fig 5: Towers of the Bridge

The height of the tower makes it very prone to damage due to the wind load. The main tower is made of steel, and the shaft has cruciform cross section which is insensitive to wind induced oscillation. However, Tuned Mass Dampers were installed inside the shafts to suppress the oscillation which was anticipated during the tower erection as well as even in the completed stage of the bridge. Tower shafts were divided into 30 tiers and almost of all tiers were composed of 3 blocks. Each block was precisely fabricated in factories and transported to the site, and then hoisted up for the erection with a self- climbing tower crane which had a lifting capacity of 1.6 MN. For the field connection high tension bolts were used. The towers and the suspended structure were coated with newly developed fluorine -resin paint which had high durability, and played important role in anticorrosion performance

Design considerations: As the bridge is located in the area which is prone to Earthquake, due attention was given to seismic design. The two earthquakes were taken into account. The first one was an earthquake of magnitude 8.5 with its epicenter just 150 m away from the bridge. The second earthquake is within 300 km from bridge site and has recurrent cycle of 150 years. Also the nearest fault line is just 90 miles away from the bridge and soil below the foundation is relatively soft. All these factors were incorporated in the design of bridge.

Tuned mass damper: Tuned Mass Damper of 10 ton was installed to specifically counter harmful frequencies of oscillation, to resist the vibration by both strong wind and earthquake. These vibrations would otherwise cause the main support towers to sway and would lead to failure.

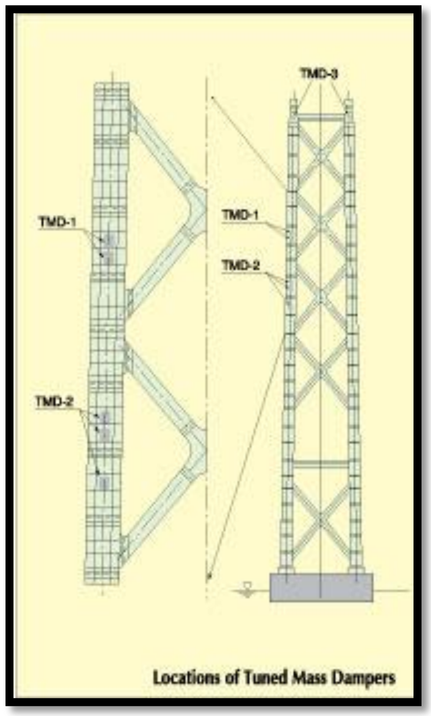
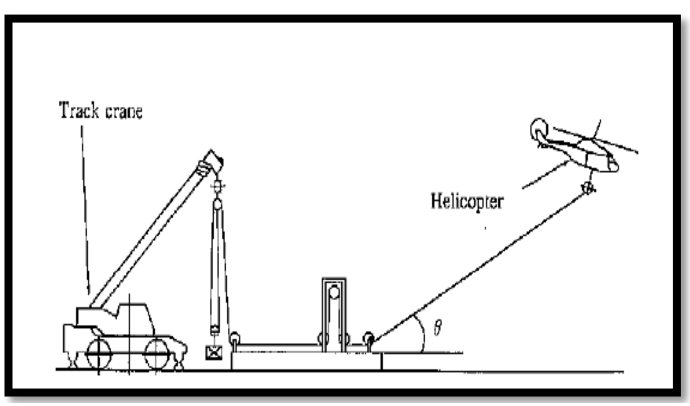


Fig 6 : Location of Tuned Mass Dampers

6.3 Challenges For Attaching the Cable With the Towers:

The main structural member carrying the load in suspension bridge is the Cable. In other structures the failure of a single deck truss member will cause a collapse but, in a suspension, bridge the rest of the structure can be unaffected as long as the cables remain intact. The main cable measures 1.1m in diameter with weight of about 50500 tons and has to support 87000 tons of deck. A cable is composed of 290 strands. Each strand contains 127 wires measured 5.23 mm in diameter. The cable was made of galvanized wire of strength 1800 N/mm^2 which avoided use of double cables per side. Sag to span ratio was kept 1:10. This sag to span ratio enabled to restrict the height of the main towers.



International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Volume 5, Issue 03, March-2019, e-ISSN: 2455-2585, Impact Factor: 5.22 (SJIF-2017)

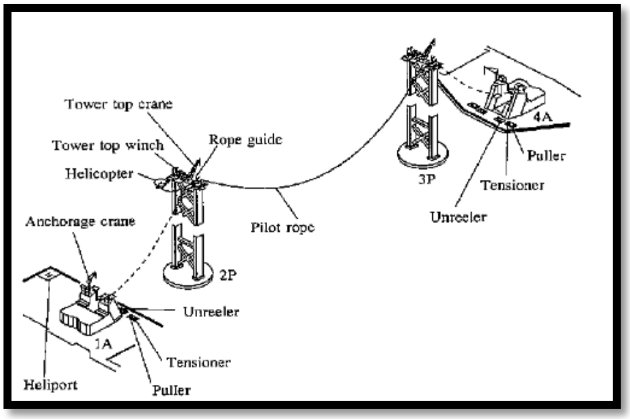


Fig 7 : Procedure for Crossing of Pilot Rope

Akashi strait has a heavy water traffic of over 1400 ships per day. So in cable erection, the 10mm diameter poly aramid fiber pilot rope was carried across the strait by helicopter so that water traffic is not disturbed.

Prevention from corrosion:

For protecting the cable from corrosion galvanized steel cables were used. The seepage of water into the cables was prevented by applying paste and paint to the cables. However, these measures were found to be inadequate. To address this challenge, dry air injection system was installed on the interior surface of main cable to keep it away from the moisture.

.

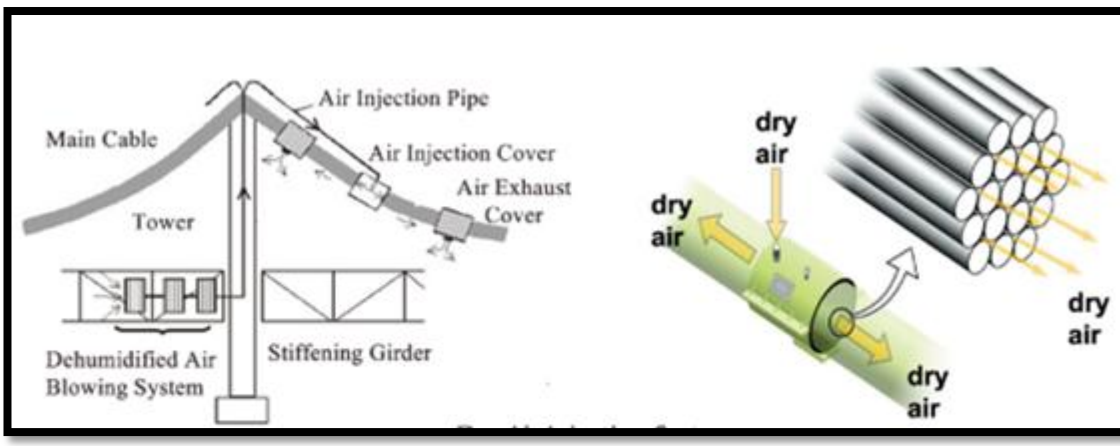


Fig 8: Dry Air Injection System

A newly developed nondestructive inspection technique that used an electromagnetic method to identify the degree of internal corrosion of the suspender ropes is also used.

6.4 Challenge For Placing Roadway:

The bridge has three spans. The central span is 1991 meters, with the end spans 960 meters each. The bridge is 3911 meters long. Initially the central span was of 1990 m, but Kobe Earthquake caused the towers to move further 1m apart. It also shifted the towers horizontally and caused one to sink and other one to rise by a small amount. The stiffened girders were not erected yet. This made structure lighter and more flexible. The deck has been designed to resist wind load and temperature stresses.

1. Aerodynamic stability

Basic wind speed for design was 46m/s. The truss stiffened girder was selected because the type was advantageous over stream lined box girder from the viewpoints of securing aerodynamic stability and easiness of the erection to be done on a strait. A boundary layer large wind tunnel in which a 40m long model was accommodated was constructed to verify the safety of this bridge against wind action.

2.Temperature:

Deck of the Akashi-Kaikyo Bridge is made of steel. And steel would undergo thermal expansion and contraction. This caused significant expansion in the length. In order to reduce the moments induced due to temperature expansion joints have been provided at regular interval. The stiffened girder has horizontal allowance of 1.45 m.

The truss members were assembled and hoisted up to the deck level at the main tower. They were supplied to the erection front and connected to the existing truss members with a traveler crane. And finally, suspenders were fixed to this newly erected portion. This method avoids disturbing the sea traffic beneath the construction and helps in securing aerodynamic stability during erection. The deck accommodates 6 lanes for motorway traffic and the design speed for vehicles is 100 km/h.

7. Anchorage:

The end span of bridge is 960 m. Both the anchorages are located on the shore lines. The body of two anchorage is conventional gravity type. The body of anchorage is made of Reinforced Concrete. Precast panels were used on exterior surface to reduce monotony. These panels have superior external appearance and make it more durable. The foundation has been constructed by using underground slurry wall method. The depth of foundation is about 61 m below ground and diameter of foundation is 85 m.

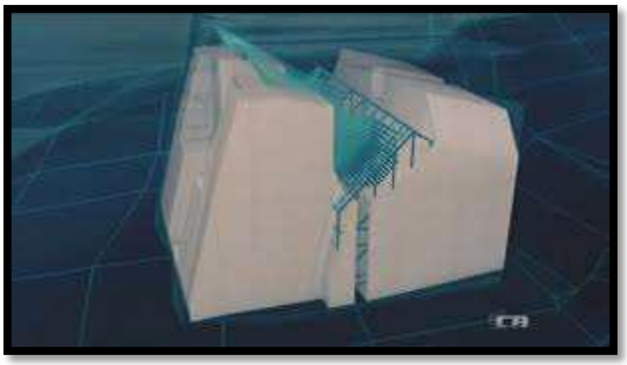


Fig 9: Model showing Anchorage block

Fig 10 : Construction of Anchorage

Conclusion:

The Akashi Kaikyo Bridge is located at a place least favorable for construction. The site is prone to earthquakes of high magnitude, high wind speed and tidal currents. Still the determination of engineers played crucial role in gifting this marvel. The techniques and the materials used in its construction have been applied globally. With the advent of carbon fiber, engineers are trying to use them in cables and if this being the case, longer bridges can be constructed. Normally as the span increases the length of the cable increases and this leads to an increase in the load to be carried by the bridge. But if carbon fiber is used, it will be lighter than steel and stronger leading to huge spans.

References:

[1] Abe, K. and Amano, K., Monitoring System of the Akashi Kaikyo Bridge, Honshi Technical Report,86, 29,1998.

[2] Bridge Engineering Conference 2007.

[3] Bridge Engineering Handbook. Ed. Wai-Fah Chen and Lian Duan.

[4] Honshu–Shikoku Bridge Authority, Wind-Resistant Design Standard for Akashi kaikyo Nippon steel technical Report no. 73 April 1997.

[5] Information about improvement for superstructure by Honshu- Shikoku Bridge Expressway Company.

[6] Wind tunnel test result and analysis methods in Historical view of long-span bridge aerodynamics by Toshio Miyata of Department of Civil Engineering, Yokohama National University, Yokohama 240-8501, Japan.

[7] Yasuda, M., Kawaguchi, K., Ohe , S., (1996) “Revised Design of the Akashi Kaikyo Bridge due to the Hyogo ken Nanbu Earthquake”, Technical Report of Honshu-Shikoku Bridge Authority,No77.

[8] www.jb-honshi.co.jp