SHEIKH ZAYED BRIDGE FOR ABU DHABI ISLAND

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1.ABSTRACT

Η Γέφυρα του Σείχη Ζάιντ θα συνδέσει το νησί του Αμπού Ντάμπι με την ηπειρωτική χώρα και αποτελεί μία πρόκληση για τους μηχανικούς και τους κατασκευαστές. Το σχήμα των κυρίως βάθρων που αποτελούνται από λοξούς προβόλους που καμπυλώνονται και στις δύο διευθύνσεις προς τη θάλασσα και τα μεταλικά τόξα που προσαρμόζονται στα βάθρα και εκτείνονται σε ύψος 60μ δίνουν μία εικόνα της δυσκολίας και περιπλοκότητας του έργου. Με την μελετήτρια αρχιτεκτόνισα Ζάχα Χαντίντ που προσπαθεί να απεικονίσει τους ασσύμετρους αμμόλοφους της ερήμου που μεταβάλονται ακανόνιστα με τον χρόνο και τον άνεμο στη γέφυρα, οι μηχανικοί για άλλη μια φορά θα κάνουν μία σύλληψη πραγματικότητα.

2. INTRODUCTION

While neighboring Dubai has its share of internationally recognized landmarks, from Burj al Arab hotel to the new Palm Island development, Abu Dhabi has so far taken a more measured approach to its infrastructure development.

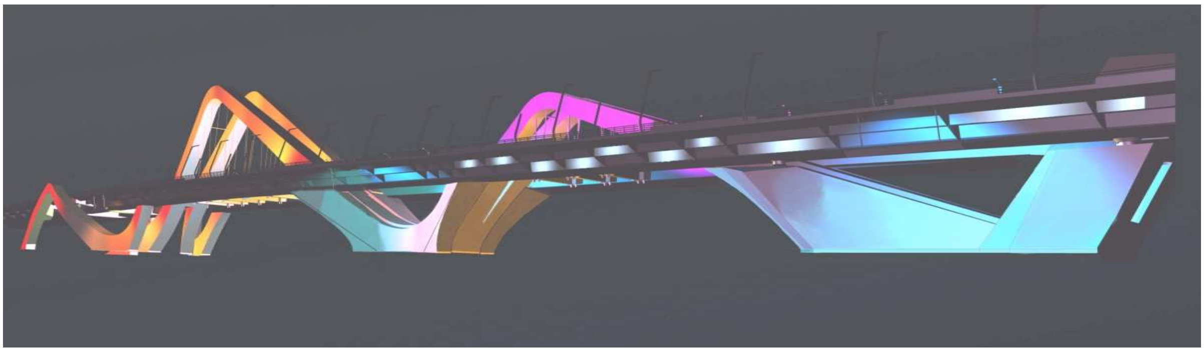

Fig.1 Overall view of the bridge with lighting concept

But in a couple of years' time, visitors to the island will drive across a dramatic new bridge that is intended to provide a gateway to the city, befitting its status as capital of the Emirates. The bridge concept which was designed by architect Zaha Hadid, was inspired by the shape of shifting sand dunes. But the asymmetric arch shape that are intended to mimic the dunes have provided many challenges for engineer in terms of both design and construction.

3. PROJECT DESCRIPTION

The main bridge has a total length of 850m consisting of 11 spans. The main span is a mere 150m in length, but size is not everything on this project. Making the sculptural, asymmetrical shape viable from a structural point of view, and building and erecting the bridge have provided challenges equal to those of some of the world's largest structures. The foundations are huge; The 'arch' shape do not act as arches, they are asymmetrical and curve in all direction; right-angle are nowhere to be found in the cross-section of the piers; these are just a few of the difficulties that the engineers have had to overcome.

Fig.2 Construction of the central pier

The main bridge is a prestressed, concrete cellular box with large crossbeams that link the two carriageways. The arches above the deck level are steel boxes, and have large cable hangers which help to support the concrete deck. The bridge has two carriageways, each with four 3.65m-wide traffic lanes, two 3m-wide emergency lanes, and a 1.5m-wide emergency walkways on the outer edge. At the west end of the bridge, on the island, the twin structures consist of three spans of 60m each, supported on concrete piers on land. The west main pier, also built on land, is the one from which the first arch takes off; this pier consists of vertical element on which the deck will be supported, and an inclined element forming the 'springing' to which the steel arch is connected. Two piers have been built in the water, in huge cofferdams, to form the supports for the main span. The two arches from the west pier lean out on either side of the road before swinging back in to the next pier, dubbed the marina pier. Through the central and eastern spans, the arches rise between the two decks; to a height of 63m on the central span.

The whole of the bridge is founded on large diameter bored piles, adding up to a total length of 16.7km of piles, most of which are 1.5m in diameter. Approximately 5,000t of sheet piles was required to build the cofferdams for the piers, and another 13,000t of structural steel was needed for the temporary works.

Fig.3 Construction of the deck using box girders and pipes

Extensive false work is being used for construction of the deck, which is being cast insitu, and also for supporting the formwork for the inclined bases of the arches. The temporary works for erecting the steel sections of the arches are also significant. By contrast the permanent works required only 12,000t of structural steel, although the bridge also needs 40,000t of reinforcing steel and 5,000t of progressing steel. A total of 250,000m^3 of concrete was also required.

4. ANALYSIS

The consultant carried out a step by step analysis to recommend sequencing of pouring concrete, stressing tendons and releasing of shuttering; to check the design of the temporary works; to set geometry to allow for elastic shortening, creep, shrinkage and temporary works flexibility, based on the actual time-frame of construction events; and to recommend heat control measures. Arches, piles and temporary works were modeled in the Adina program as beam elements, pile caps were modeled as grillages, the top and bottom flanges of deck box girders as shell elements, and all other parts as solid elements, with several solids comprising any cross-section. This resulted in a model with 51,000 elements, 164,000 nodes and 594,000 degrees of freedom. The computer needed 6GB of RAM. Some 3,300 post-tensioning tendons were totally modeled

5.TEMPORARY WORKS AND ERECTION

The piling and pilecaps for the marine piers were constructed inside huge, double-walled cofferdams. Pours of up to 3,500m^3 were typical for pile caps, which had to be poured in stages. Falsework consists of tubular steel columns supporting longitudinal girders on which transverse formwork trusses are placed. Screw jacks below the columns will allow the formwork to be released after casting.

Fig.4 Falsework system for the construction of the piers

The twin decks are multi-celled, prestressed concrete box girders with cantilevered 'fins' along each outer edge, featuring an open soffit which will be used to accommodate special lighting. Complex falsework systems has been developed to support the pier formwork. Tubular steel columns are the mainstay of the modular system- they are of 3m and 6m heights, with make-up sections and these are arranged on a plan grid of typically 5m by 6m, all supported directly on piles.

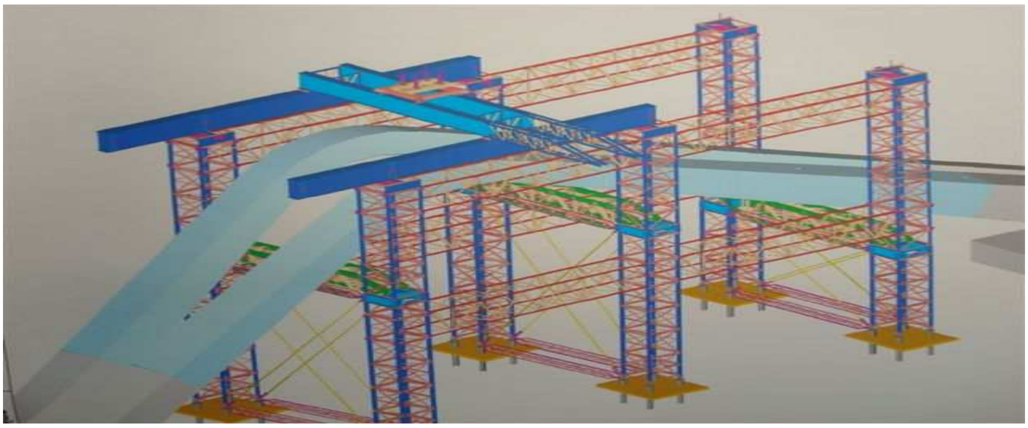

Fig.5 Temporary support towers for the erection of the arch segments

On top of the columns is a system of primary beams, topped by secondary beams which run longitudinally. Additional stools are used to make up the differences in height for the curved, inclined pier shape. Flexible formwork panels are used, which can be warped by the use of props, in order to form the curved surfaces required. On the steeper parts of the piers and arch bases, top formwork is also required.

Erection of the steel sections is expected to be one of the most challenging parts of the project. Not only are the sections significantly heavy, they will have to be lifted up to 60m high, aligned with the twisting, curvy arches, and welded into place under these tricky conditions. Specialist subcontractor in supplying the strand jacking equipment that will be used for the erection process. A system of temporary towers will be built around each arch location, incorporating crane beams topped with strand jacks, to lift the sections from the barges. These sections will be up to 670t in weight, making the lifting process a challenging operation even if size were the only factor. There are 22 separate pieces which will have to be raised between 30m and 60m above the sea level, and connected by butt welding.

6.SEISMIC DESIGN

Seismic protection requirement on the structure are significant, and the system has been designed to provide this protection includes viscous damper and fuse links with particularly high capacities. The bridge is required to withstand seismic events with ground accelerations in the order of 0.25g. This will be provided through the use of fuse restraints, viscous dampers and elastic restrainers acting in parallel to limit the deck movement and associated forces, while dissipating seismic energy. The fuse restraints are designed as rigid links that can withstand lateral loads and minor earthquakes up to a predetermined force. Under a specified earthquake, the fuse links are designed to fail, leaving the damper elastic restrainers free to provide an optimum structure period shift and the associated energy dissipation that is required.

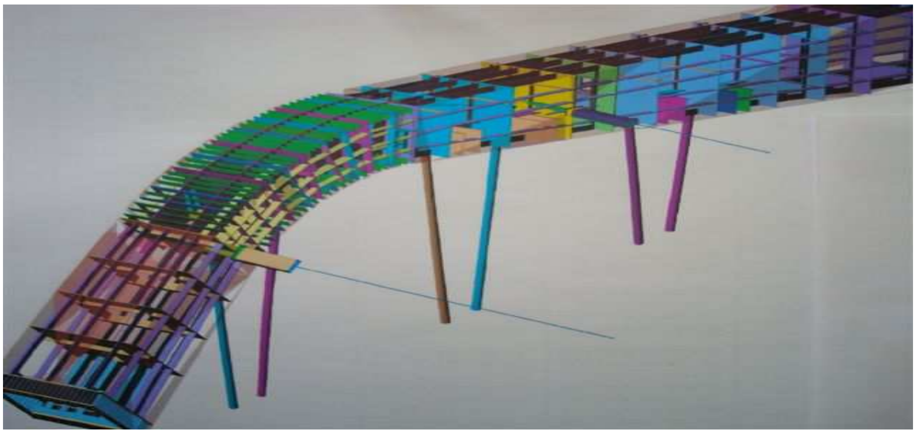

Fig.6 Cad model for the arch stiffener plates and hangers

These are characterized by their load capacity-failure loads ranging from 2,950kN to 18,580kN depending on where they are located on the structure. These are believed to be amongst the largest in the world. Likewise, the viscous dampers have a load capacity range of between 3,350kN and 5,100kN exceeding the usual standard for this type of element.

7.CONCLUSIONS

For the construction of Sheikh Zayed bridge, steel has been the predominant material for all the formwork and falsework structures, taking advantage of its geometrical and re-usability capacities as well as material properties. Erection of heavy lifting structures (600t) over the sea has proved a very challenging task with the steel piles embedded on the rock layer providing adequate stiffness with the use of X- bracings. Extensive use of box girders with longitudinal and transverse stiffeners can provide solutions for heavy loads on large spans over the sea, or to maintain access of the trucks below the falsework system. Finally, construction analysis with the appropriate software and modeling the stiffness of the pouring stages in mass concrete structures is a tool to provide economy and safety to the supporting structures.