

Design of the Main Spans of the Chongqing Caiyanba Bridge

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Summary

The new Caiyuanba Bridge over the Yangtze River in Chongqing will carry six lanes of highway and two pedestrian walkways on its upper deck as well as two tracks of monorails on its lower deck. It will serve as one of the transportation backbones for this ever-expanding city, connecting the two busiest business districts of the city: Yuzhong and Nan'an. Because the bridge is located at the center of the city and is visible from most parts of the city, aesthetics is a very important matter. After careful study of the location, a slender tied-arch was selected to carry the double level bridge girder over the Yangtze River. Upon completion, its 420-m span will be the world's longest tied-arch span for combined rail and highway traffic. The side spans are 102 meters long.

Keywords: Bridge, Long span bridge, Arch Bridge

1. Introduction

The mighty Yangtze and its tributary to the north, the Jialing River divide the metropolitan Chongqing into three parts, as shown in the project location map in Figure 1. The Caiyuanba Yangtze River Bridge is a key project connecting segments of the newly planned south-north corridor. Located 1.2 kilometers upstream from the existing "Chongqing First Yangtze River Crossing," which was built in 1978, the Caiyuanba Yangtze River Bridge is situated in the heart of the town, and will be a vital transportation link for city of Chongqing.

The crossing is to carry six lanes of highway on its upper deck and two lanes of monorails on its lower deck. The project consists of a signature tied-arch with the record span of 420 meters, and the south and north approaches – the Sujiaba Interchanges connecting the main bridge to the southern shore, and the Caiyuanba Interchange connecting it to the northern shore.

The final design was completed in November 2003, and official ground-breaking for the project took place on December 28, 2003. When the bridge is completed at the end of 2005, it will be the longest arch span for combined rail and highway traffics in the world.

2. Development of Main Span Structural System

Because of its location, the bridge is visible from most parts of the town. Aesthetics is an important factor in the design. The general public of the City prefers an arch bridge. A panel of bridge experts appointed by the City subsequently accepted the recommendation of the designer, a joint venture of Chongqing Communications Research Institute, Chongqing and T.Y. Lin International, USA to build a half through tied-arch at this location.

The Department of Water Transportation determined that a bridge at this specific location must provide a minimum navigation clearance of 392 meters. This resulted in a main span of 420 meters.



Figure 1 Project Location



Figure 2 Renderings of the Tied-Arch

The water level of the Yangtze River in the Chongqing area varies significantly seasonally. The difference between the high water level and the low water level can be as much as 30 meters. The dry season is from about November to about May each year. During the dry season only a small portion of the river is navigable while in the high water season, the entire riverbed is under water. As a result, the piers of the main span should be sufficiently tall to put the superstructure above the high water level.

Most vessels on the Yangtze River are barges carrying cargos with a total weight of up to about 5,000 tons. To resist possible barge collisions, the piers and the lower portions of the arch rib are made of prestressed concrete.

The portion of the arch above the deck is a pair of steel boxes. The box section was selected for its slender appearance, which is very important for a centrally located city bridge. The arches are further inclined inwards to achieve a more slender



Figure 3 Elevation

appearance. This inclination also improves the stability of the structure.

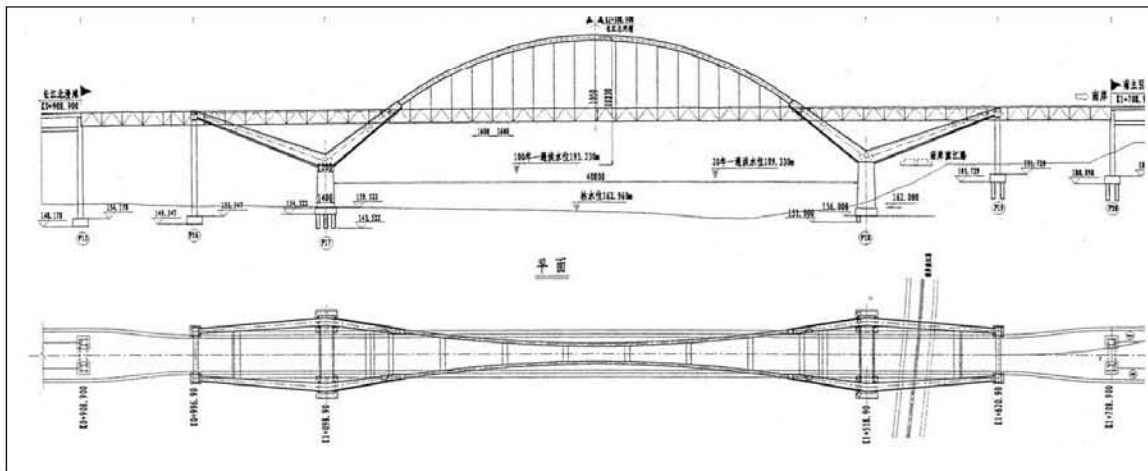


Fig. 4 Plan and Elevation

The truss is 11 meters deep to provide sufficient clearance for the monorail, the loading of which is among the highest in the world. To further increase the slender appearance of the structure, the truss is spanning the end spans without intermediate strut supports. This is possible because the 11-meter-deep truss itself has sufficient stiffness to span the 102-meter end spans. Deletion of vertical struts in the end spans makes the bridge look much more graceful.

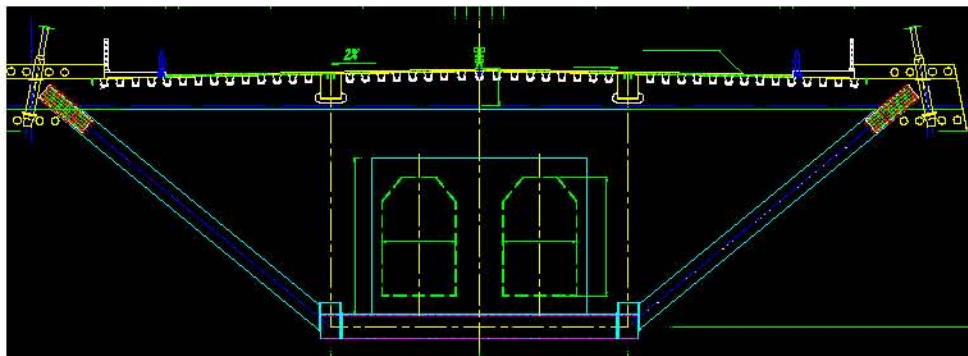


Figure 5 Typical Girder Cross Section

3. The Girder

The 11-meter-deep steel truss is similar to a Warren Truss. The hangers are spaced at 16.00 meters on center so the truss is configured accordingly. In the mid span, the hangers are anchored to an extension of the floor beams. The anchor points coincide with the centerline of the arches. A diagonal strut at each side of the girder carries the hanger load to the bottom of the truss.

The truss is continuous over five spans. In the main span, the truss is suspended by cables from the inside legs of the rigid frame. The approach spans are concrete box girders.

With six lanes of highway and one pedestrian path on each side, plus barriers and space for hangers, the total width of the bridge deck is 43 meters out to out. The deck is a steel orthotropic plate with floor beams spaced at 4.00 meters on centers. The ribs are trapezoidal and are 8 mm thick. The deck plate is 16 mm thick.

Box sections are used for the bottom chords. Most diagonals have an H section. Shop splices are mostly welded and field splices are bolted using high strength bolts.

At the lower level, the bottom chords are horizontally braced. Transverse floor beams at 16-meter

spacing supports the steel box shaped rails for the monorail.

The deck will have pavement of either epoxy asphalt or SMA.

4. The Arch

The lower portion of the arch is a concrete frame. Concrete is selected to provide better resistance to possible barge collisions. Aesthetically the heavy concrete frame also offers a more sturdy appearance for the structure. The outside legs of the concrete frame are anchored vertically with vertical tendons that are adjustable so that a known vertical tie down force can be assured. The front legs of the concrete frame penetrate above the deck so the connection between the concrete legs and the steel box ribs is located above the deck level. Horizontal ties are placed at the deck level to stress the legs together. These ties are also adjustable.

The concrete frames are prestressed using strand tendons.

The upper portions of the arch ribs are steel box sections, 2.40 meters wide and 4.00 meters deep, constant along the entire length. Diaphragms inside the ribs are provided to stiffen up the hollow box section. Longitudinal stiffeners are simple plates. The box ribs are to be delivered in sections and will be welded together at the site.

It is intended to keep the humidity sufficiently low to prevent corrosion inside the box by mechanical ventilation.

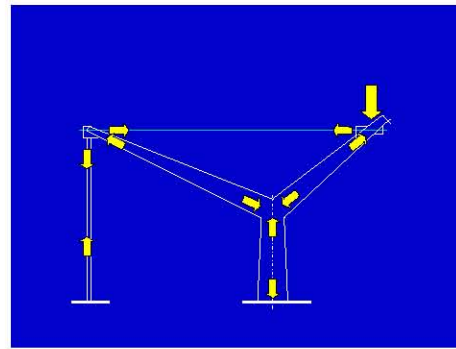


Fig. 6 Structural System of the Concrete Frame

5. The Hangers and Ties

The hangers are parallel wire strands with Hi-Am type sockets. The upper end of the hangers penetrates the bottom plate of the arch rib and is anchored at a diaphragm inside the box rib. The bottom end of the hangers is provided with threads and is anchored at the floor beams of the deck. The hangers are located in the same center plane of the arch ribs.

The ties are made up of seven wire high strength strands. They are individually sheathed. Each tie is divided into three sections. The center section anchors at the inside legs of the concrete frames, while the other two connect the inside and outside legs. Each tie can be individually stressed. They can also be individually replaced without interrupting traffic.

Both hangers and ties are made to meet the same standard for stay cables in cable-stayed bridges and must provide the same level of safety and durability.

6. Foundation

The soil is generally soil rock. The foundations are supported by 3.00-meter-diameter short caissons.

7. Construction

There are three major difficulties in the construction of this structure: the variable water level, the restrictive city area for material transportation and the short construction schedule.

During high water season, the Yangtze River is very rough. It can rise up to 30 meters above the low water level. Building the foundation during high water would have required very heavy cofferdams, the price of which would be prohibitive. Therefore, the foundation must be completed during the dry season, which usually runs from November to about early May. To expedite the construction, all caissons are hand dug at the same time. Fortunately, this is not a major problem in China at the moment as labor is relatively readily available.

It is anticipated that all piers will be completed to a level above the high water level before high water arrives. Then the rest of the construction will be free of the interference of the high water.

Due to the restrictive city traffic, most materials, including the steel sections of the girder and the arch will be delivered to the site by barges. However, the large difference in water level makes docking and handling very difficult. In addition, the navigation channel is located on one side of the river during dry season so it is difficult to access from the other bank of the river. Consequently, it was decided to use a heavy-duty double high line to lift and to erect the steel sections directly from the barges.

The arch ribs will be erected using the high lines and a temporary cable-stayed system with its pylons located above the main piers. The advantage of the high lines is that they can lift the steel sections from a barge at the navigation channel, which is near the southern bank, and transport them to any place of the main span. The girder will also be erected by the same high lines after the arch ribs are completed.

8. Design Specifications

The bridge is designed according to the Chinese specifications. For the orthotropic deck, the design is also supplemented by AASHTO specifications. For hangers and ties, the design is supplemented by PTI's "Recommendations for Design of Stay Cables."

Chongqing is not a seismically active area. Seismic effect is not significant for this structure.

9. Acknowledgement

The owner of the bridge is Chongqing City Investment Company. The designer is a joint venture of Chongqing Communications Research Institute and T.Y. Lin International. The contractor is Zhongtie Major Bridge Construction Company.