

# Design & technology characteristics of main bridge of Chaotianmen Yangtze River Bridge

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**ABSTRACT:** The Chongqing Chaotianmen Yangtze River Bridge has a main bridge of 932m (190m+552m+190m) long, half-through steel truss tied arch structure. The bridge has double levels, of which the 36.5m wide upper deck has dual three-lane and sidewalks on both sides, and the lower deck carries two lines of municipal light railways and two highway lanes on each side. The steel truss of side span is installed by means of cantilever method with the assistance of provisional supports; while the steel truss in middle span is installed using sling pylon by cantilever method, and finally closed in the span mid. This paper mainly describes the structural design, construction method and technology characteristics of half-through steel truss tied arch bridge.

## 1 GENERAL INTRODUCTIONS

The Chongqing Chaotianmen Yangtze River Bridge is located 1.7 km downstream the confluence of Jialing River and Yangtze River. This bridge is an important passage connecting the central urban business regions on both banks of the Yangtze River in Chongqing. It consists of the south approach, north approach, and the main bridge. Total length of the bridge is 1741m, of which the 932m main bridge is a (190m+552m+190m) half-through steel trussed arch structure which records of arch bridge worldwide(Fig.1). The bridge has double decks, of which the 36.5m upper deck has dual three-lane and sidewalks on both sides, and the lower carries two lines municipal light railways and two lanes to either side (Fig.2).

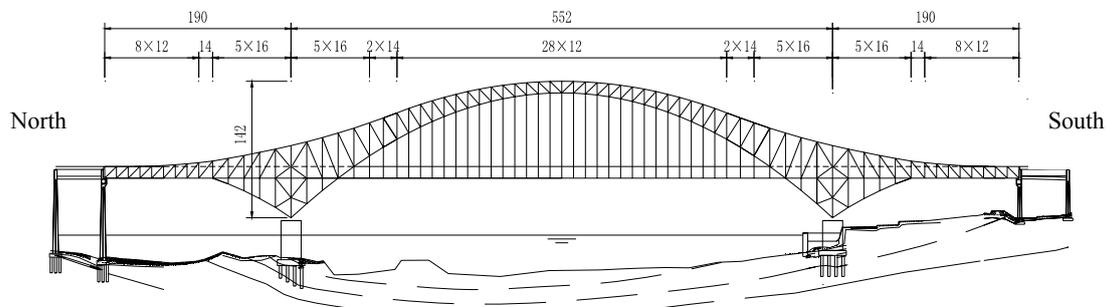


Figure 1: Arrangement of Chaotianmen Yangtze River Bridge (unit: m)

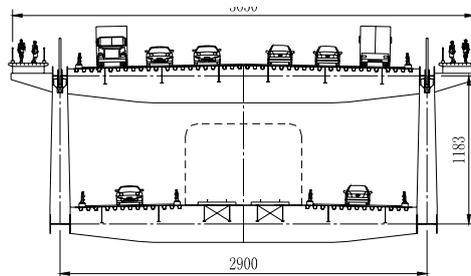


Figure 2 : Cross section of bridge (Unit: cm)

## 2 STRUCTURE COMPONENTS AND SUPPORT SYSTEM

The main bridge is a (190m+552m+190m) continuous steel tied arch truss structure; the main truss, comprises of two pieces of truss, is 29m wide. The end span is a steel truss of variable height, and the middle span is a tied steel arch truss. The height between the arch top and the middle support is 142m, the outline of the lower arch chord is a quadratic parabola with 128m arch rise. The upper chord of arch is also a quadratic parabola transiting to the circle curve of 700m radius on upper chord of end truss span. The main truss adopts “N” shaped truss of variable height, the arch truss height is 14m at mid-span, 73.13m at middle pier(stiffened chord of arch rib is 40.65m), and 11.83m at end pier. Due to the big difference of arch truss height and the aesthetic consideration, the truss panels have three lengths: 12m, 14m, and 16m. Two levels of ties are set in the middle span, at 11.83m spacing. The upper tie is only connected to the lower arch chord; while the lower tie goes through the whole truss including the middle chord at the stiffened leg and the lower chord in the end span. As suspenders are adopted to connect these lower and upper ties, it ensures that the structure holds the advantages of “steel arch with soft beam”, which simplifies mechanical performance, and improves stress arrangement and vertical deformation of the bridge deck (Duan xuewei and Xu wei 2006).

With double floor ties in main trusses, the bridge is a self-balanced structure without any thrust forces. Therefore, the support system is designed like the continuous beam bridge. Spherical bearings are adopted, the maximum bearing force at middle support is 145,000kN. In longitudinal direction, hinged fixed bearings are arranged at middle pier on north side, and movables on the rest piers. Two transversal restrictions bearings are designed at the middle of the lower crossbeam of side supports. The central transversal restrictions can make the transversal displacement induced by thermal forces of main truss to both sides well-proportioned, so as to avoid the rail deformation.

## 3 MAIN TRUSS DESIGN

In the past, the traditional steel truss is usually designed with one single material and the same width of each chord member. To adapt the large inner force variety of the chord during construction and service (from 89,520kN to 2,290kN), the main chord is fabricated with three type of steels, Q345qD, Q370qD and Q420qD, with maximum thickness of 50 mm. Q420qD is the first time used in large quantities on steel bridge; and the height and width of chord member sections are variable correspondingly; the section width has two types: 1200mm and 1600mm. The members are spliced at four sides; with uniform height and width at splicing joints to make the splicing convenient. For a member, the height and width not vary at the same section, the web members adopt “H” or “王” shaped sections, shown in Fig.3, to meet different forces.

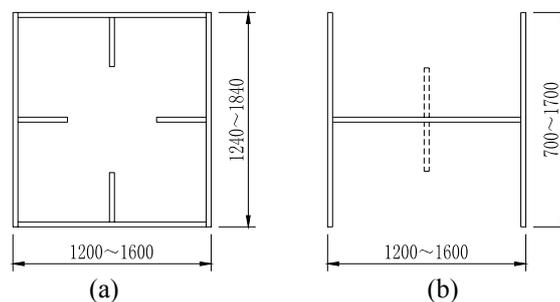


Figure 3 : Section of main truss members (unit: mm) : (a) “H” shape section, (b) “王” shape section.

With the advantages of better integrity and simplified construction work, the monolithic panel joints are widely adopted on steel truss bridges these years. While, considering the structural characteristics of this bridge, particularly the majority of joints are not conducive for standard production, it will increase an extra invest on manufacturing equipment, measures and precision control. Thus splicing panel joints are preferred to facilitate manufacture and save costs. However, the panel joints forces at middle support are very concentrated, and the adjacent

members have large dimension and thickness, with maximum depth of 80mm, so monolithic panel joints are adopted here; splicing panel joints are adopted on the rest parts of main truss.

Aiming to facilitate connection between main truss and the bridge deck, steel bracing members are adopted to connect on the lower chord joints of the ribs. “H” shaped welded members are used for upper bracing members; while for the lower bracing members, it combines a “王” shaped cross section and an assistant cable made by high strength externally prestressed tendons. Those cables are aimed to decrease forces beared by lower bracing members. As a result, it could cut the size of the bracing members. Therefore, four assistant cables are set for each truss on lower bracing members. Each cable is anchored on an inner anchorage box and the joints where connect lower bracing chord and arch ribs. The cable, containing 55 strands, is tensioned to 20,000kN. Cross section and cable anchorage detail are shown in Fig.4.

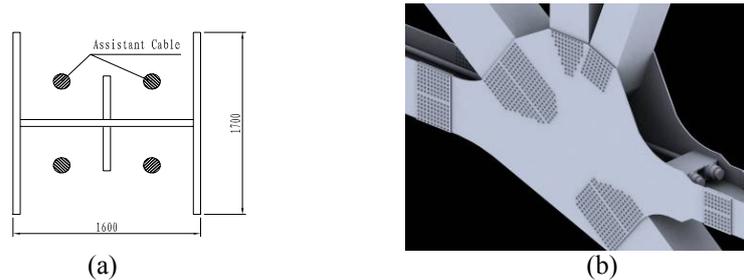


Figure 4: Lower Bracing Member Section and Anchorage Detail of Assistant Cable (Unit: mm): (a) Lower bracing member section, (b) Anchorage detail of assistant cable.

Suspenders used in main bridge are applied the high strength parallel strand cable, PES7-127, PES7-139 and PES7-151. Anchorage boxes are enabled to stable the suspenders between lower chords of the rib and upper bracing joints. Double suspenders are set on each suspension point to facilitate replacement.

#### 4 BRIDGE DECK DESIGN

The orthotropic steel plate is applied for upper deck and lower deck system. The steel plate is 16mm thick, with closed “U”-shape ribs. Steel diagrams at an interval not exceeding 3m are arranged longitudinally. The upper deck has six longitudinal girders in its cross-section; the lower deck has two longitudinal girders respectively on each side, and transversal girders to be set at main truss panel joints. The process of force transmitting is, bridge deck → “U”-shape ribs → diagrams longitudinal girders → transversal girders → main truss. On the upper deck, sidewalk brackets are to be set outside main truss panel joints, and “[]” shaped orthotropic steel plates to be laid on the brackets. The section is shown in Fig.5.

In order to simplify the mechanical condition, it is separated between the bridge deck and main truss in original design. As for the corresponding acted condition in service, it avoids negative effect caused by dead load or part of live load by adjusting the length of steel deck (Duan xuewei et al.2009).

After site temperature tests during bridge deck welding In the summer of 2008, it found that there were a 15°C variety between the upper bridge deck and the main truss, and 6°C between lower deck and the main truss. For a full steel bridge, there is no relevant provisions in code worldwide for thermal effect of each components on the same floor in sunlight, it is a main technical concern encountered during the construction of this bridge.

As for the negative effects of the plate truss caused by thermal variety, further studies of relevant solutions are conducted. Therefore, the plate truss proposal is partly updated by adding three connections on joints and three connections within joints between deck and main truss respectively. These connections can transmit shear force when plate truss under thermal effect to control the side deformation and stress in appropriate scope of transversal beam of the bridge deck end. Connection on joints of plate truss is shown in Fig.6. In the summer of 2009, after a

site survey of these connection points, it indicates that the partly connected method for plate-truss is very effective.



Figure 5 : Upper and lower decks of Main Bridge



Figure 6 : Connection configuration

## 5 JOINTS DESIGN

The joint system for the main truss included the upper and lower longitudinal plane joint systems for the arch ribs and the lower deck longitudinal joint system.

The main truss width is larger than panel length, so the upper and lower plane longitudinal bracing adopt diamond type, and the stiffened chord's plane bracing adopts "K" shaped type. Because of some inclination existing between the adjacent plane bracing, the gusset plate should be bended to adjust it. At the figure center of "米" shaped plane longitudinal bracing, a truss transversal bracing is set for each two panels of main arch rib, hence it enhances space rigidity of arch rib, and reduces the calculated free length of diagonal rod. At the zone of stiffened leg, one truss transversal bracing is also arranged for each panel.

## 6 STEEL GIRDER INSTALLATION AND DESIGN

It is possible to adopt temporary piers on both south and north end spans of the main bridge as the south end span is located on the shore, and the north one is exposed on beaches in dry season. The main bridge adopts three-span continuous hinge bearing support system, it is statically determinate structure, simplified supported structure and cantilever structure, for each girder on both sides before closure in middle span. On both sides, the main girders will not induce extra force by vertical or longitudinal movement, which provides a favorable condition for the installation of the main bridge.

The end span should be installed by cantilever method on trestles and temporary piers. First, two panels of steel truss was installed on the trestles by means of tower crane beside end pier; next, the erection gantry was assembled on the upper chord of steel truss; then the erection gantry installed the steel trusses in sequence with assistance of temporary piers from end pier to mid pier. While installing steel truss, some balanced weight should be layed on the end span to make sure that the stability coefficient is larger than 1.3.

The steel truss of mid span was installed by symmetric full cantilever method with the assistance of sling pylon, and finally closed at mid-span. When the middle span reaches a big cantilever, the stress of each member is controlled by the sling pylon system. The sling pylon is 100m high, having two levels of cable; While installing middle span, the steel girder should firstly be installed to 108m high, The steel truss should be installed first, and then the arch rib truss and suspension robs were installed step by step until the mid-span was closed. Furthermore, it should also be forced on the designated region of end span to ensure the safe coefficient larger than 1.3. The lower chord of arch rib truss should be closed prior to the upper chord.

After arch truss closed, the temporary tie should be installed and stressed to form a stable structure aiming to enhance construction safety control. The deck crane walks on the upper deck to install the rest upper and lower ties and crossbeams in sequence until mid span is closed, and then the sling cables and sling pylon should be removed. The deck crane goes backward from mid-span to install crossbeam, plane bracing, and longitudinal girder of lower deck, and install upper and lower steel bridge deck.

The assistant cables are installed and stressed after all bridge members completed. When auxiliary facilities and pavement completed, the assistant cables and suspension rob force should be adjusted to meet design requirements. The arch ribs before they were closed in the middle span are shown in Fig.7.



Figure 7 : Arch ribs before closure in mid span during construction

The steel girders were started to assemble in September 2006; In January 2008, the arch ribs were closed; and the closure of tied chord was finished in May. It is in good agreement with that as it is designed during installation and closure process. There is also no on-site structure dimension amendment, additional drilling and demolishing during construction, and it was successfully closed in the middle span with no extra stress by using theoretical size of components.

## 7 CONCLUSIONS

Construction of the bridge was begun in Winter, 2004, and finished on 29th, April, 2009, shown in Fig.8. It has recieved great compliment by people from many fields and become a new landmark and city symbol for the “Bridge Capital”, Chongqing. Nowadays, the steel truss arch bridge is gaining more application across the nation. Not only the design and construction of Chaotianmen Yangtze River Bridge, but also the issue of plate truss thermal effects and its solution can bring valued experience for bridges of similar type.

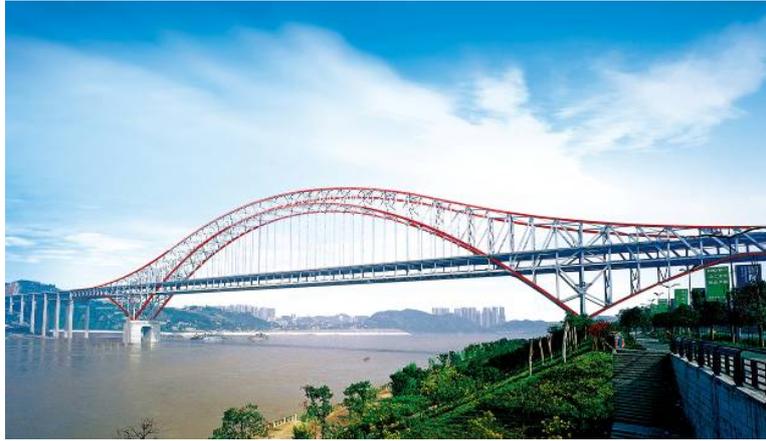


Figure 8 : Rendering of Main Bridge after completed

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