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DESIGN OF THE SECOND HIGHWAY BRIDGE OVER YELLOW RIVER IN ZHENGZHOU, CHINA

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Abstract. *The Second Highway Bridge over Yellow River is located in the national highway trunk linking the north to the south from Beijing to Zhuhai in Guangdong Province. The total length of the bridge is about 10km. It carries 4 lanes in each direction in one of the two separate bridges. The main part consists of 8 identical 100m simply supported spans. The arch rib is dumb-bell shape that composed of two Concrete Filled Steel Tubes (CFST) and connected by three cross braces. The arch ribs are tied by longitudinal prestressed concrete box girders. This paper deals with the criteria that determined the choice of the structural design, the major consideration in design and the main stages of construction.*

1 INTRODUCTION

The Second Highway Bridge over Yellow River in Zhengzhou, China, is a key engineering project in the national highway trunk (express way) linking the north to the south from Beijing to Zhuhai in Guangdong Province. There are two separate bridges in the road section; each bridge carries 4 lanes in a direction and has a net width of 19.484 m. The bridge with a total length of 9848.16m is divided into an 800 m-long main bridge and a 9035 m-long foreshore bridge as well as two abutments. The foreshore bridge is composed of 127 and 81 spans of PC simple beam bridges with a span of 35 m and 50m, respectively as well as 27 spans of PC slab bridges with a span of 20m. The main bridge crosses the major stream channel and the dyke in the south bank.

For economy reason, it is no doubt to choose simple beam and slab structure as the foreshore bridge. However, for the main bridge, various structures, including PC simply supported bridge with a span of 50m, PC continuous girder bridge with a main span of 125m, cable stayed bridge with a main span of 210m and CFST arch bridge with a main span of 135m were examined and compared during the design process. At last the scheme of CFST arch bridge, total of 8 spans, each with a span of 100m was selected as the main bridge. The main reasons are as follows:

- Bridge with 100-m span was suitable for the major stream channel of Yellow River. This span is an economic span for a CFST tied arch bridge;
- Arch bridge provide good looking and conscious experience to the driver;
- CFST arch bridge has been developed rapidly in China.

Construction began in 2001 and will be completed in 2004. This paper will introduce the design and construction of the main bridge of the Second Yellow River Bridge in Zhengzhou.

2 SUPERSTRUCTURE

The tied arch is supported by four bearings of 1750t rubber basin carrier. Both fixed and sliding supports are used. The fixed bearings are placed in the two ends of adjacent spans on the same pier where the deck is continuous. Thus, the deck is continuous 200 m-long. Sliding supports are placed on the other pier where XFⅡ-160 expansion joint is fixed in the deck. The longitudinal grade of the five spans in the north is 0.0%. The other three spans in the south are in a vertical curve with a longitudinal declin of 2.6% towards south. The elevation is shown in Fig. 1.

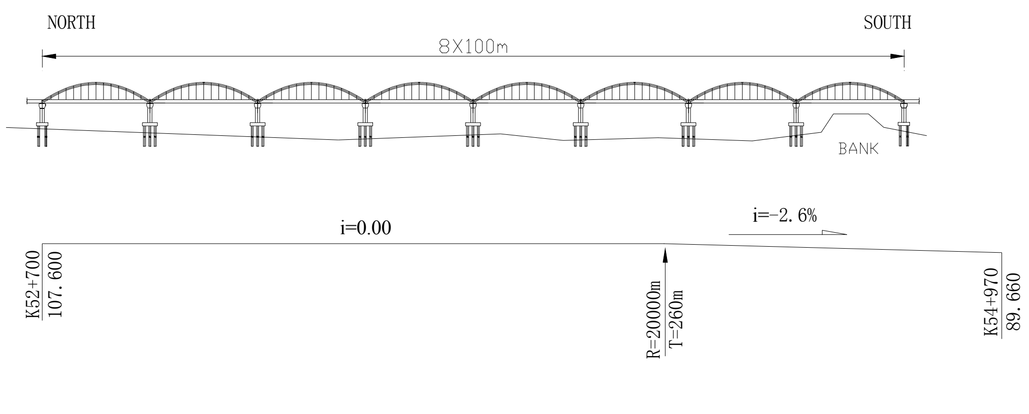


Fig. 1 Elevation of the main bridge

The length between neighboring piers of one span of CFST tied arch is 100m. The calculation span is 95.5m. Ratio of rise to span of the arch rib is 1/4.5. The main bridge adopts cantenary curve with a parameter m of 1.347 as its arch axis. The distance of two rib's center is 22.377m and three hollow steel tubular braces (one straight line member and two K-shaped braces) connect two arch ribs to form the space structure. The configuration of superstructure is illustrated in Fig. 2.

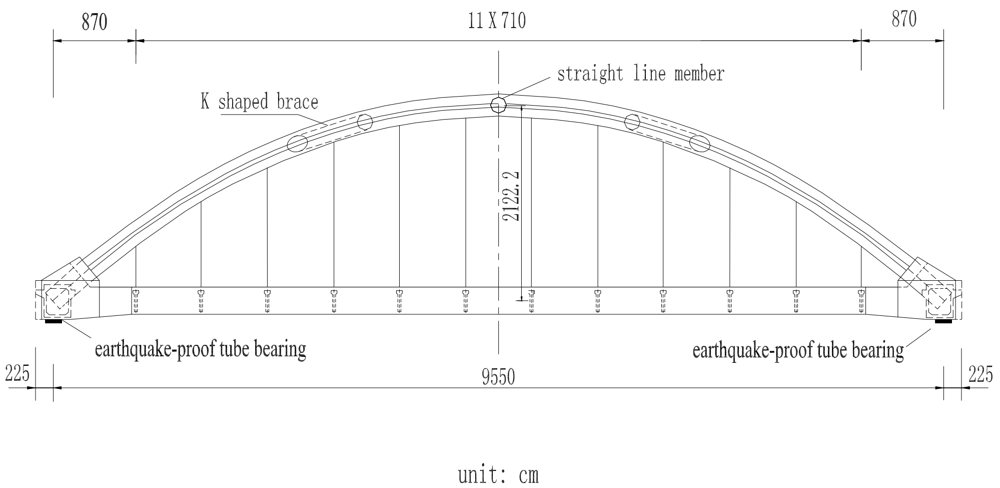


Fig. 2 General view of a standard superstructure

Each bridge comprises two 2.4 m high arch ribs of dumbbell cross-section. The steel tube has a diameter of 1000mm and thickness of 16mm and is filled with C50 concrete (Fig. 3). The dumbbell section is generally used as arch rib when the bridge span varies from 60m to 120m. It is composed of two CFST tubes and two web plates. It can provide large flexural stiffness than single tube, make the fabrication easier and give a simple view compared to truss section.

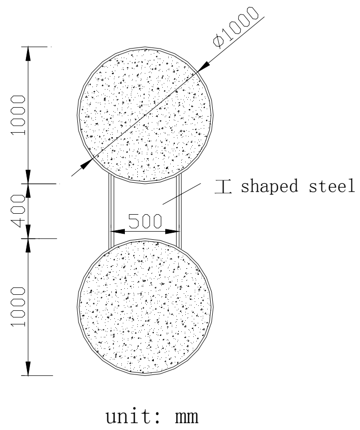


Fig. 3 Cross-section of arch rib

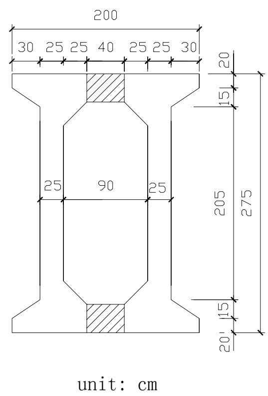


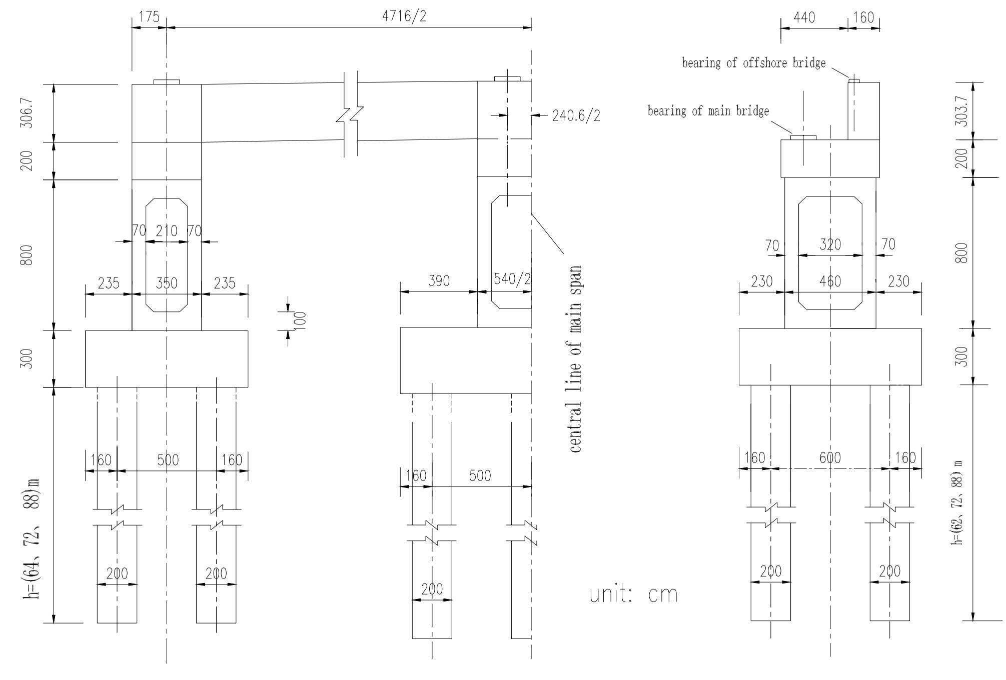
Fig. 4 Cross-section of tie beam

The hanger is made of 91Φ7mm high tensile strength wires protected by two layers of Polyethylete with cold cast button head anchorages. The tie beam is a pre-stressed concrete box girder with 2.0m width and 2.75m high (Fig. 4). The longitudinal distance of two neighbor hangers is 7.1m. The end floor beam is PC box girder high 2.9m and wide 3.22m. Total of 12 hanging PC cross beams connected to the tie beams and the cross beams support the precast RC π-shaped slabs which will be situ casted concrete into bridge deck slab.

3 SUBSTRUCTURE AND FOUNDATION

The two separate superstructures are laid on a unitary substructure (Fig. 5). One pier composed of three RC box column and caps. There is a lateral beam when the column is higher than 7m. The 2.0% transverse slope of deck is realized by the different height of the pier columns.

Soil investigations at the site indicate that the upper part mainly includes sandy clay, silty sand and some tenuous piece of clayey soil; the lower part mainly includes fine sand, middle sand and clayey soil entraining with gravel or pebble. Friction piles with diameter of 2.0m are selected as foundation.



(a) elevation (b) transverse view

Fig. 5 General view of substructure and foundation of main bridge

The two side pier columns are supported by a pile foundation that consists of four piles and a 3.0m high RC pile cap. And the central pier column adopts 8 piles and a 3.5m high RC pile cape as its foundation. There are three lengths of the piles, i.e., 64m, 72m and 78m. In deciding the length of piles, three riverbed sections are considered, that is, the section measured in the location surveys, the section considering the maximum likely scour depth after the bridge is built and the section filled up by the sand and soil from the upstream. The data from the test piles in other two nearby bridges over the Yellow River is taken as reference for the skin friction coefficient

4 CONSTRUCTION

According to the construction organization and the schedule, the superstructures of the main bridges total of eight spans could be constructed span by span or several spans at the same time, and the two half-width bridges of one span can also be constructed one by one or both at the same time. Since it was necessary to build the bridge in a short time, erection was optimized by working simultaneously in the shop and on site. Repetition of the 8 span, 16 similar superstructures, the conceptual simplicity of their assembly and that most of the members are precasted that permit rapid fabrication and erection on site.

4.1 Shop production

A steel tubular arch rib was divided into 5 segments. Steel plates were rolled and welded to form a tube with straight seams by the embedded arc auto welding method. Arch rib curve was composed of spliced straight steel tubes. Every straight steel tube was about 1.8-2.0 m long.

Each section should be 1:1 laid out before assembling on the work platform, which could meet the layout size. Each rib should be pre-assembled on the ground including at least three segments, i.e., a springing section, a middle section and a crown section.

All steel members fabricated in the shop were blast cleaned and treated with a protection/coating cycle. The outer skin of steel tube was protected by aluminum-coating system, which was created by electric arc thermal spraying method. The web plate of dumbbell arch rib and the steel tubular bracing members were protected by paint. The inner surface of the CFST member without paint or coating should be cleaned of oil and other foreign material in order to ensure the connection of filled concrete to the steel tube. Field coatings included the cover coat and the revisions were prescripted by erection procedure.

The deck slabs, the cross hanging beams and most parts of the tie beams were fabricated in nearby fabricating yards.

4.2 Erection

At first, two temporary bridges(Fig. 6) were constructed along the two sides of the bridge to be built. All the substructures and foundations were built of cast in situ reinforced concrete. Working platform at each pier was built for piles and substructures.

The erection of so many members was very challenging. A special gantry crane with lifting capacity of 600kN (Fig. 7) was designed and erected for the handling of the steel tubular rib segments and other precast PC or RC members. The crane can move along the rail on the temporary bridges. The calculation span of the crane is 66m (clear span is 64.8m), clear height is 47m, and lifting height is 43m.

Fig. 6 Side view of temporary bridges

Fig. 7 Gantry crane

Fig. 8 View in the deck

Fig. 9 Installation of cross beams

There were 6 segments of tie beam along the longitudinal axis. The two segments embedded with the spring segment of arch rib were casted in situ with the end floor beam by falseworks. Each precasted tie beam segment was divided into two I-shaped members once more in the transverse direction. The precast segments were fixed on 6 props.

After the end floor beams and the tie beams had come into being a plane frame, the steel tubular arch was built up with three segments on two props. Every segment was about 30 m-long with a maximum weight of 36t. They were lifted into place by the 600kN mobile crane. The segments were temporarily connected by the inner Flange. After the measurement and adjustment of the axis of arch rib, they were welded together to make steel tubular arch rib. The two arch ribs were connected by three steel tubular bracing members (two K-shape braces in the quarter point and one straight member at the crown) (Fig. 8).

Concrete was pumped into tubes from the two spring sections to the crown. Hangers were built to link the CFST dumbbell rib and tie beam. After complete positioning and installation of all cross beams (Fig. 9), the RC π-shaped slabs were placed on them and concrete were casted into longitudinal gaps between adjacent slabs and transverse gaps between slabs and cross beams to form continuous deck of a span. The pavement of the roadway was covered by a wearing course of 9cm of bituminous concrete, under which a cusion course of 8cm of steel fiber concrete was laid.

During the construction, tie beams were pre-stressed by stands according to the design requirement. The forces of the hangers should be adjusted two to three times to satisfy the force distribution between the arch rib and the tie beam and the alignments of the arch rib and the tie beam.