Design and analysis of Xiyangping Bridge in Zhangzhou, China

S. Tang and W. Cai
Highway Bureau of Zhangzhou, Fujian, China

B. Chen and G. Peng
College of civil engineering in Fuzhou University, Fuzhou, China

ABSTRACT: Xiyangping Bridge, situated in Zhangzhou, Fujian Province, China, is a half-through rigid-frame tied arch bridge. It consists of three spans. The central span is a half-through CFST arch with a span of 150m and the two side spans are cantilever reinforced concrete deck arches. The ribs in central span and in the two side spans are fixed at the arch seats. Tied bars of high tensile strength anchored at the two ends of the side spans balance the thrust forces of the arch. This paper presents the design, analysis as well as construction of this bridge.

1 INTRODUCTION

Zhangzhou in south-east of Fujian Province, China, has nine counties and a district under its administration, covering an area of 12,607 km^2 and having a population of 3,760,000. This area is aboundant in narcissus, so it is well-known as the "Hometown of Narcissus". The Jiulong River with a width of 350m-400m runs through it, which is the second longest river in Fujian Province. There are many famous bridges over the river, such as the Jiangdong Bridge and Zhanbei Bridg. The former is an old stone girder bridge built during 1190 and 1194, which a span is composed of 4 stone girders of 23.7m long, about 1.7m wide and high, has a weight about 180 tons and is imagible to be erected in ancient time without modern hoisting machines. The latter is a one panel, two pylons extradosed prestressed concrete bridge with a main span of 132m, as shown in Fig. 1. It is also the first extradosed prestressed concrete bridge in China.

Figure 1: Zhanbei Bridge

Connecting the south developing area to the north industry and education districts Xiyangping Bridge will play an important role in local economic developing and road network. The winning design is a half-through arch bridge by Southwest Jaida Civil Engineering Design

Co., Ltd in the design competition. The total length of 770m of the bridge is divided into three parts, the main three span concrete filled steel tubular (CFST) arch bridges and each 9 spans of 30m continuous girder in south and north approaches. The deck with a width of 33m carries four roadways and two side walkways.

The main three-span bridge is a CFST 'fly-bird-type' arch bridge. The central span is a half-through CFST arch and the two side spans are reinforced concrete deck half-arches. For the main bridge, comparison between two alternative schemes was carried out. Scheme 1 is a general 'fly-bird-type' arch bridge, which is not difficult to design and built because 20 of such bridges built in China (Chen 2006) can be reference for it, and it is simple and can conform to its surroundings and environment. In Scheme 2, the central span is a lift-basket arch which is difficult to erect by cantilever method and the half-arch in the two side spans is degenerated to a solid girder with variable cross-section which will cause unclear structure behavious and cost increasing. At last, according to the design concept of simple and harmony to environment, Scheme 1 is chosed as the final one.

(a) Scheme 1 (b) Scheme 2

Figure 2 : Image view of Xiyangping Bridge

2 STRUCTURES

In Xiyangping Bridge, both the CFST arch ribs in central span and reinforced concrete arch ribs in side spans are fixed at the springing to form a rigid-frame structure with the piers and their pile foundation. Prestressed tie bars of high strength wires anchored at the ends of the two side spans balance the arches' horizontal reaction forces. Total of 230m of the main bridge consists of the central 150m and two side spans of each 40m length (Fig. 3).

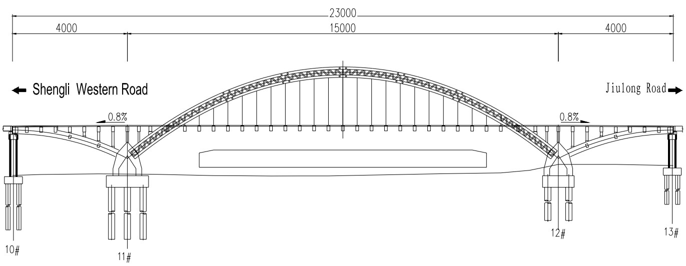


Figure 3: General layout of Xiyangping Bridge

There are two CFST arch ribs in the main span with a center-to-center distance of 19.5m. The arch axis is a catenary and the rise-to-span ratio is 0.2. The main arch rib consisits of a CFST truss with width of 2.1m and height of 3.65m. The four chords are Q345c steel tubes with 850mm diameter and 14mm thickness (in the spring section the thickness increases to 16mm), and filled with C50 concrete. Two of them in both upper and lower levels are welded together by two Q345c steel plates. The vertical and diagonal members are steel tubes with 351mm diameter, thick of 10mm. The cross section of arch rib is shown in Fig. 4.

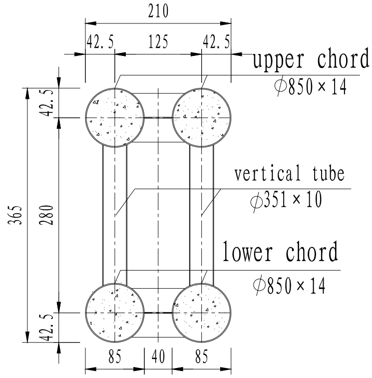


Fig. 4: Cross section of arch rib

Reinforced concrete transfering girders at deck level and 5 steel tubular truss bracings at the arch ribs with a distance of 20m above the deck are provided as lateral bracing systems for the main arch structure. The steel tubular chords utilize ϕ500×12mm welded tubes, while the web members are ϕ299×10mm seamless steel tubes.

The half-arch in the two side spans has a span of 40m and rise of 9.88m, giving a rise-to-span ratio of 0.1235. It has two rectangular reinforced concrete ribs of 4.0m high and 2.5m wide in general section and 3.19m wide in the section near the spring. Bracings are also reinforced concrete beams.

Tied bar for one arch rib is made of 6 steel strands of 37ϕ15.24 with strength of 1860MPa and protected by Polyethylene. There are 23 pairs of hangers, each one has a steel wire of 121ϕ7mm coated by zinc with a standard strength of 1670Mpa. The hanger are also protected by two PE layer coats have adjustable chilled cast anchors at its two ends.

The general cross prestressed concrete transvers beams suspended by cable hangers or supported on spandrel reinforced concrete columns are 26.1m long with I-shaped section. pre-cast RC deck slabs on transvers beams was covered by 9cm thick steel fiber concrete and 6cm thick modified asphalt to form the road wearing layer.

Cushion cap, 4m high, 14.7m long and 28.7m wide, is made of solid reinforcement concrete. There are 12 drilled piles with 2.2m diameter as the foundation of the main pier.

3 STUCTURAL ANALYSES

A 3-D FEM structureal model was built for structural analyses. All the main elements of bridge structure including arch rib, deck structure as well as substructure and foundation were treated as spatial beam elements, except hangers and tied bares were treated as cable elements. All data implemented to the FEM model were collected on the basis of the workshop drawings. This model made in ANSYS environment has 1280 nodes and 2395 elements of 33 kinds, as shown in Fig. 5.

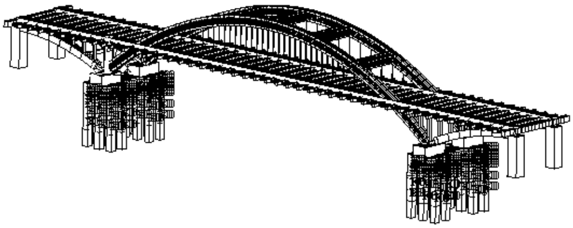


Figure 5: Spatial FEM model of Xiyangping Bridge

Presented FEM model was used to calculate internal forces and deflection of the bridge under static loads. The design was based on Chinese codes, including the Criteria of the Municial Bridge Design (CJJ 11-93), the Standard of Loadings for the Municipal Bridge Design (CJJ 77-98), General Code for Design of Highway Bridges and Culverts (JTG D60-2004) and Code for Design of Highway Reingforced Concrete and Prestressed Concrete Bridge.

It was obtained from the calculation results as follows: impact factor of 1.18, load distribution factor 1.1 and load no reduction in live-load intensity both in longitudinal and transverse directions. The pedstrain load is 0.31 ton/m^2. Temperature-induced forces are calculated for the bridge structure by a range of mean temperature of bridge in $\pm 20^0$C and 10^0C increasing in the top of box girder. Maximum deformation was obtained at the quarter, loading half span as shown in Fig. 6 and corresponds to a flexion of 2.1cm much less than the allowable value L/800=18.75cm.

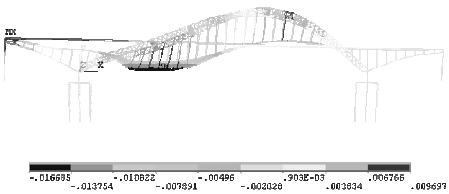


Figure 6: Deformed shape for half span loading

Eigenvalue buckling analysis was carried out to verify the buckling characteristics of the arch structure. The first buckling mode is out-of-plan in symmetric shape (Fig. 7) with a load 8.26 times of the design one. It shows that the arch has small stiffness in the horizantal direction than that in vertical direction.

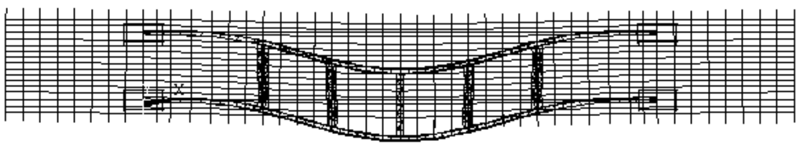
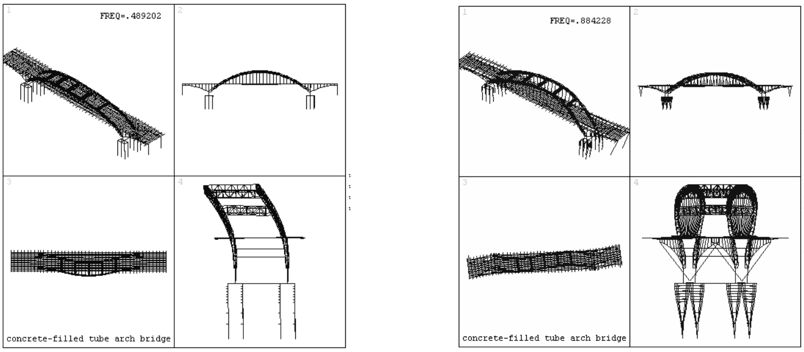


Figure 7: Collapse modal under maxium moment at crown

The first 5 mode shapes and the corresponding frequencies were obtained from FEM analyses on the model, as presented in Table 1 and Fig. 8. The first horizontal frequency of 0.4892 is much lower than the first vertical frequency of 0.8842.

Table 1: Dynamic frequencies and modes of the main span

No.	Frequency（Hz）	Mode
1	0.4892	Out-of-plane symmetric vibration of arch rib
2	0.8842	Out-of-plane antisymmetric vibration of arch rib and deck
3	0.9171	Out-of-plane opposite direction vibration of arch rib and deck
4	0.9888	In-plane antisymmetric vibration of arch rib and deck
5	1.184	In-plane antisymmetric vibration of arch rib and deck



（a） Mode shape of first order （b）Mode shape of second order

Figure 8: Vibration Mode shapes

4 CONSTRUCTIONS

The substructure and foundation construction works in this bridge were relatively straightforward. Two temporary bridges 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 two side spans of half-arch ribs were concreted in-situ on centrings. The steel tubular arch ribs in central span were shop fabricated and erected by gantry crane (Fig. 10). The steel tubular arch was built up with five segments on four props. The segments were temporarily connected by the inner Flange (Fig. 11). After the measurement and adjustment of the axis of arch rib, they were welded together to make steel tubular arch rib. And then bracings were erected to connecte the two arch ribs to form a spatial structure.

Figure 10: Temperay Bridge and Gantry Crane

Figure 11: Connection of Arch Rib Segment

The two CFST arch ribs have been closed at 8th Feb., 2007. After that, concrete will be pumped into the steel tube chords and fabricated transverse girders and deck slabs will be erected. The Xiyangping Bridge is still under construction and is expected to be completed in 2007.

REFERENCES

Bao-chun Chen, Jing Gao, Huai-ying Zheng, 2006, Studies on Behaviors of CFST "Fly-bird-type" Arch Bridge, *Proceedings of the International Conference on Bridges, Dubronvnik, Croatia, May 21-24, 2006*, SECON HDGK, Dubronvnik, Croatia: 205-212