Researches on key techniques of Dongping Bridge in Fuoshan City, China

B. Fan
Design and Research Institute of Highway Planning and Surveying of Sichuan, China

T. Mu
Design and Research Institute of Highway Planning and Surveying of Sichuan, China

J. Liang
Design and Research Institute of Highway Planning and Surveying of Sichuan, China

ABSTRACTS: Dongping Bridge is an important bridge for its key position. The structural design, construction methods and the experimental research on Dongping Bridge in Foshan City are introduced in this paper. In addition, the new techniques applied and developed during the design of the bridge are briefly explained.

1 INTRODUCTION

Dongping Bridge, over Dongping River in south part of Fuoshan, is an important bridge for its key position. It was a nice and the architecturally valuable structure which was the basic input for designing of the new bridge. The over arch structure, a continuous-beam cooperation-system, was simplified and get accustomed to the environment. It is a steel-arch with a main span of 300m and side span of 95.5m, as shown in Fig.1. The width of the bridge is 48.6m comprising a roadway 30m and two 6m wide footpaths.

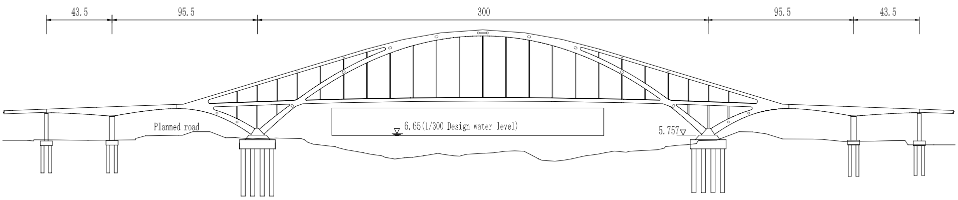

Fig 1: Bridge Elevation

This paper outlines the technical difficulties met in Dongping bridge, and after some technical innovation and researches on them, some feasible scheme were proposed and applied in the design and construction.

2 DESIGN

2.1 Main arch rib

The main span of Dongping bridge, with a calculation span 292.9m and rise span ratio1/4.55, adopts catenary curve with a coefficient 1.1 as arch axis. The arch is made up of three 1.2m wide box section arch ribs of which in structural depth of 3.0m above the bridge deck and 3.0 to 4.5m below the deck. The sub arch rib is under main arch rib with 2.0m high and composed of straight line and circular curve. The main arch rib and sub arch rib are combined at the crown segment with height from 4.0m to 7.2m, as shown in Fig.2. A special brace with pipe-type cross section of 1420×2240×20mm is set at the distance of every two hangers (or column).

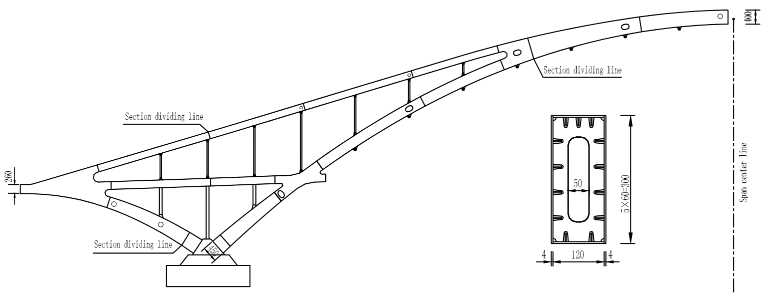

Fig 2:Diagram of Arch Rib

2.2 Side span arch rib

The semi-arches of side spans at both sides of the riverbank are of parabolic curves with a clear span of 49.1m and rise-span ratio of 1/6. It is 1.2m wide and the height of it changes gradually from 3.0m to 4.5m. The arch ribs are incorporated with the sub arch rib and the ties at the end, shown in Fig.3.

The side arch ribs are filled with concrete of C40. The steel box and concrete are anchored together by PBL (Perforbond Lriste) connector, which is a kind of shear resistance connector by making holes on the longitudinal stiffening rib. The column on the side arch rib are ‘H’ shape steel of 1.2 × 0.8m, and the cross braces between the rib are 820×20 steel tube.

2.3 Deck system

The deck system is steel-concrete composite structure composed of latticed deck beam, which include 3 longitudinal main beams (i.e. tie bars), 2 longitudinal sub-beams and some cross beams, 8mm thick steel plates set on the latticed beams and 12mm thick concrete on the steel plate. The latticed deck beams are all connected with high strength bolts, shown in Fig.4.

Fig.3: Erection of Side Span Arch Rib

Fig.4: The Latticed Deck Beams

2.4 Steel hangers and ties

The 3 longitudinal main beams, with a box cross section of 1.2×2.2m, are both served as the deck system and the ties for balancing the horizontal thrust of the arch ribs. Fig.5 shows the assembling of the tied bars. Assembling joint jacks are provided at the middle of the main span for jacking the steel strand on the final assembling joints.

The spandrel columns and hangers are all ‘H’ shaped cross section of 1.2m width, same with the width of main arch ribs, sub arch ribs and steel tie bars. High strength bolts are used to connect the hangers and arch ribs, steel ties. In order to improve the wind resistance of the bridge, all the hanger and web plates of upper spandrel columns are reasonably designed to have holes and openings (Fig.6).

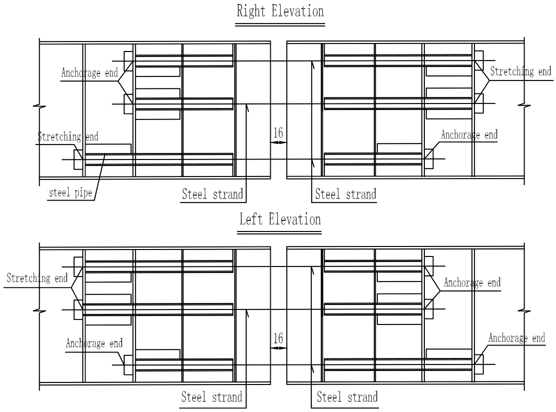

Fig.5: Assembling of the tied bars

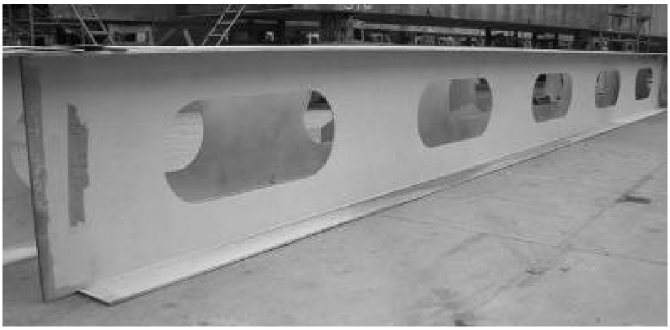

Fig.6: Hanger with opening

2.5 Joints between Steel and concrete

As the aforementioned, there are three arch ribs for the main arch. But with regard to the approach, it is a continuous girder bridge with a superstructure of five beams. So two beams remained can't be connected with the arch rib. Therefore, the strengthened end cross beam were arranged to form rigid connection among arch rib, beam and their deck slabs, it can be seen in Fig.7.

3 EROSION RESISTANT COATING FOR STEEL STRUCTURE

The concept of the erosion resistant coating was one of the key factors in the successful construction of a steel bridge. After careful analysis of the climate and other natural conditions of the construction site, the erosion resistant coating of the steel structures is designed as the following:

Zinc silicate primer of 20μm thick to be applied at the workshop + Alcohol-dissolvable inorganic zinc rich paint of 75μm thick + Epoxy closing coat of 25μm thick + Epoxy iron paint of 100μm thick + acrylic-acid polyurethane finish course of 2×50μm thick (one course to be applied at the workshop and another applied on site). The total dry film thickness of the paint shall be 300μm.

The interior steel box shall be coated with zinc silicate primer of 20μm thick in the workshop +

Epoxy zinc rich primer of 75μm thick + Epoxy finish course of 100μm before closing the box. The total dry film thickness of the paint shall be175μm.
The aluminum spraying technique was applied to the connection of the high strength bolts.

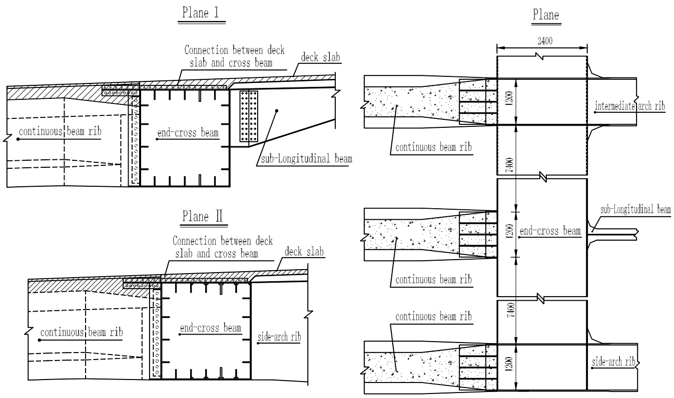

Fig.7: Steel-Concrete Joint

4 CONSTRUCTION

4.1 Horizontal swing method

The main arch rib consists of main arch and sub arch. During rotation of the semi-span , the sub arch serves as stays to balance the main span and side span. At the mean time, since the side span arch rib is of steel-concrete composite structure, so it is possible to take advantage of its heavier weight to balance the main span in horizontal rotation, as shown in Fig.8.

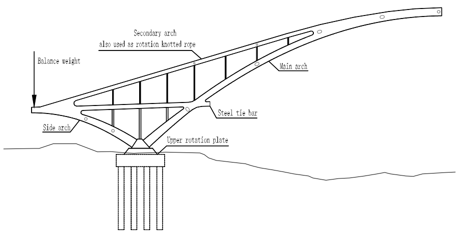

Fig.8: Typical Structure Sketch of Horizontal Rotation System

4.2 Vertical swing method

Taking construction progress and cost into consideration, the temporary vertical hinge was set at the spring of the main arch, and then the half span was hoisted by lifting tower to the final position. Fig.9 shows the process of vertical rotation, and Fig.10 is the photo before the vertical rotation.

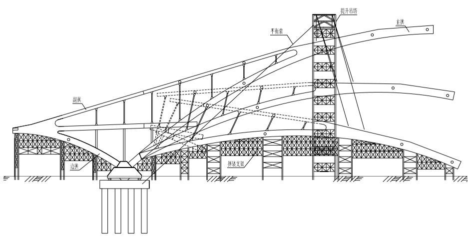

Fig.9: Process of Vertical Rotation

Fig.10: Photo of Vertical Rotation

5. ECONOMIC INDICATER

Table 1 shows the material consumption for the main bridge. It can be shown that, in the super large span bridge structure, the steel-concrete composite structure arch bridge is more economic.

Table 1 Material quantity for the main bridge

Item	Quantity	Consumption
Concrete (m^3)	54358	$1.94m^3/m^2$
Steel (t)	21093	0.78 t/m^2
Cost (Million RMB)	292.36	0.0104million/m^2

Note: The total length of the main bridge is 578m with a total area of 28090.8m^2. The consumption in table 1 is equal to quantity divide the total area.

6. KEY TECHNIQUES APPLIED IN DONGPING BRIDGE

The bridge designs, which have been introduced, fulfill all demands of requirements according to China code. Moreover, the following innovative techniques are applied in the design of Dongping Bridge:

6.1 The design of the joints of steel and concrete in steel arch-continuous girder cooperation system.

6.2 The main arch and sub arch can cooperate as the stress member, which not only make the bridge rich in shape, but also make it economic

6.3 The structure is simplified by the application of pipe type brace between the arch ribs, and also the traveling comfort is improved.

6.4 Taking the durability of the structure into consideration, steel structure was applied in hangers and ties.

6.5 The deck structure consists of the steel-concrete slab and 50mm thick asphalt concrete pavement, because the temperature difference is considerate in the bridge location.

6.6 In order to facilitate rotation and reduce the stress at the arch spring, the steel-concrete composite structure subjected to eccentric compression was applied at the side span arch and the spring of main span arch

6.7 For cooperation with arch rib of the main bridge, the ribbed continuous girder is applied in the approach.

6.8 In the construction of the main bridge, the main arch ribs are assembled on the scaffolding on the bank, and when they are hoisted vertically to the right position, they are then be rotated horizontally to the final position.

6.9 Based on the specific characteristic of the bridge, some technical requirements were provided, such as the fabrication of steel structure, mainly on strength of welding seams, inspection on the quality of welding seam, welding seam repairing and grinding techniques and installation precision of steel structures on site.

7 SCIENTIFIC TEST AND RESEARCH

In order to guarantee the above-mentioned design techniques, some experimental researches on Key Techniques of Design and Construction of Large Span Composite System Arch Bridge, was carried out according to the specific characteristics of the bridge. The main contents are as the follows:

7.1 Structure system innovative design research of large span composite system arch bridge

7.1.1 Design research on cooperation system of steel arch and continuous girder, which include the research on structural design, analysis and comparison of plane calculation results, analysis of stability, dynamic and wind resistance performance of this system.
7.1.2 Study of co-mechanical behavior the main arch ribs and sub arch ribs, which include, Constitutional design of arch ribs of the main span, mainly the joints of bifurcated and trifurcated brunches,The calculation of internal force, and its distribution, co-work performance of main arch rib and sub arch rib.
7.1.3 Technical studies on steel ties, steel hanger and pipe type brace, which include the design of their structure and cross section, and their fatigue calculation and the measures.

7.2 Experimental researches on steel-concrete composite structure

7.2.1 Experimental research of steel-concrete composite deck slab
It mainly includes the investigation and study on the connecter between steel and concrete, and the experimental researches on structure performance under static load and dynamic fatigue load. Based on the performance of the deck slab, the model test was carried out under positive moment and negative moment, as shown in Fig.11 and Fig.12.

Fig.11: Model experiment of the deck slab under positive moment

Fig.12: Model experiment of the deck slab under negative moment

7.2.2 Experimental research on steel-concrete composite beam, mainly on connection between steel box and pre-stressed concrete, and its performance under bending load, as shown in Fig.13.

Fig.13: Steel Box Concrete Beam Test Model

7.2.3 Experimental research on steel-concrete joint, mainly on structure design of the joint of steel box and concrete, and the structural performance of the joint under static and dynamic bending load, as shown Fig.14.

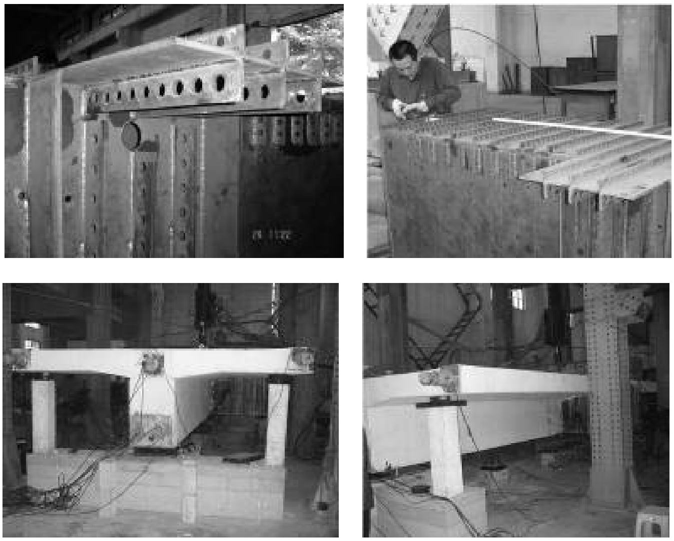

Fig.14: Experimental Model of Steel-Concrete Joint

7.3 Cooperation performance of Steel-Concrete Composite Structure by Optical Fiber Grating instrument

The precise measurement of contacting surface of steel plate and concrete in the composite deck slab has long been a technical problem. Because the randomness of location of the damages, it is essential for the sensors to have distributive testing capacity. Meanwhile, the sensors must be sensitive to the status of both the steel and concrete. So until now, there are no suitable measurement methods. Therefore, FBG sensor was applied in the model test, which successfully performed the skid monitor in the model test, as shown in Fig.15.

7.4 Experimental Research on Rotation Process

7.4.1 Experimental research on vertical swing of the main arch rib, which include structural design of horizontal swing process, i.e. rotation system, upper and lower rotation board and driving power system design, and analysis of the results of plane and space calculations in horizontal rotation system.
7.4.2 Experimental research on horizontal rotation of the arch bridge, which include structure design of vertical rotation process, including rotation system, vertical rotation hinge, lifting tower and lifting system, and results analysis of plane and space calculation of vertical rotation system.

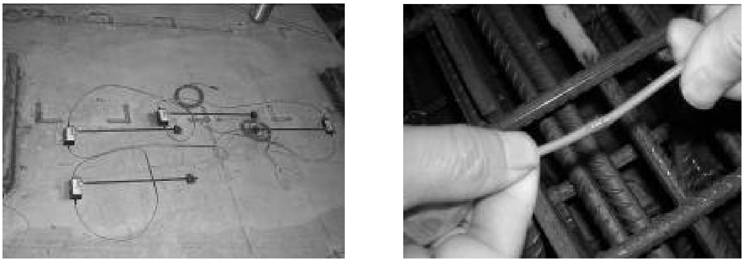

Fig.15: The arrangement of Optical Fiber

8. SUMMARY

Thanks to the innovative design and the researches on the bridge, the construction of Dongping Bridge begun in April, 2004, and it was successfully completed in September 18, 2006.