CONTINUOUS DESIGN OF CANTILEVER BEAM OF CFST HALF-THROUGH ARCH BRIDGE

X. Zuo[1], X. Liu[1], L. Ren[2], S. Tan[2], G. Shang[2], W. Li[3]

[1]Hunan road & bridge construction group Co., Ltd, Changsha 410004, CHINA.
[2]CCCC FHDI engineering Co., Ltd., Guangzhou 510230, CHINA.
[3]Shaoguan public utilities board, Shaoguan 512031, CHINA.

e-mails: rely999@163.com, liangren1031@gmail.com

SUMMARY

Simple-supported bridge deck system is widely used in the half-through arch bridge over the past decades, but there existed some problems during the long-term use, including cracks of deck pavement between the connection of adjacent joint, the caving of part deck pavement due to the failure of any suspender, and so on. Therefore, taking a 111m main span Baiwang bridge in Shaoguan in Guangdong as example, a floating continuous frame system is introduced to the design of cantilever beam in CFST half-through arch bridge, which realized the load sharing between longitudinal girder and cross beam and the continuous cantilever beam. The results can be as reference in the same design.

Keywords: *CFST arch bridge, half-through, floating continuous frame system, cantilever beam, continuous design.*

1. INTRODUCTION

CFST arch bridge is a new rapid developing bridge since the 1990s in China. According to incomplete statistics, the number of constructed and under-construction CFST arch bridges in China amount to more than 300. There have a lot of advantages for CFST arch bridge, including giving full play to the material performances of steel tube and concrete, convenient construction and nice shape[1]. Especially the steel tube is the bearing scaffold and template during the construction stage, as the part of the structure during the completed stage, which saves the template and decrease the cost. So CFST arch bridge is widely used in long-span bridges[2].

Now the suspension structures (the deck structure under the suspender) of half-through and through arch bridge usually adopt floating simply-support suspended system, i.e. the suspenders hang the cross beam, bridge deck places on the cross beam, and the small longitudinal girders are located between the adjacent cross beams[3]. But there have exposed some problems during the long-term use, including cracks of deck pavement between the connection of adjacent joint, the caving of part deck pavement due to the failure of any suspender, and so on, which seriously affected the safety of the bridge service life[4-5]. Therefore, taking Baiwang bridge in Shaoguan in Guangdong as example, a floating continuous frame system is introduced to the design of cantilever beam in CFST half-through arch bridge to realize the load sharing between longitudinal girder and cross beam and the continuous cantilever beam.

2. PROJECT PROFILE

Baiwang bridge in Shaoguan in Guangdong is a city bridge across Bei river, as shown in Fig. 1. The total length of the bridge is 798 m, and the general layout of the bridge is 3×16 m (continuous girder of reinforced concrete hollow slab) + 2×16m (simply-support prestress hollow slab girder) + 3×5 m (box rib arch) + 14×16 m (simply-support prestress hollow slab girder) + 111 m (CFST half-through arch bridge) + 2×55 m (box rib arch) + 2×16m (simply-support prestress hollow slab girder). The following will introduce the detailed design.

Fig. 1. *Scenery of Baiwang bridge in Shaoguan in Guangdong.*

2.1. Layout of half-through arch bridge

The half-through arch consists of three arch ribs, and the corresponding rise span ratio is 3.33 with the net-span of 111.44 m and the net-rise of 33.45. The vehicle load is truck-load 20 and trailer 100 basing the old Chinese Code, and the crowd load is 3.5 kN/m^2. The width of the deck is 30 m, as shown in Fig. 2, which consists of sidewalk 3 m, arch rib 2 m, the bicycle lane 1.5 m , carriageway 7.5 m (two lanes), arch rib 2 m, carriageway 7.5 m (two lanes), the bicycle lane 1.5m, arch rib 2m and sidewalk 3 m.

2.2. Design of steel tube arch rib

The section of arch rib chooses three-tube type after optimizing, as shown in Fig. 3. The height of middle arch rib is 2700 mm, including a top steel tube with the diameter of 1800mm and two down steel tubes with the diameter of 850 mm. While the height of arch ribs on both sides are 2200 mm, including a top steel tube with the diameter of 1300 mm and two down steel tubes with the diameter of 850 mm. Steel tubes are manufactured by rolling the smooth A3 steel slabs with the thickness of 14 mm.

For three-tube type arch rib, the advantages include: (1) resulting in low gravity center and excellent lateral stability, which realizes the closure construction under single arch rib, as shown in Fig. 4; (2) saving a lot of temporary lateral stable facilities; (3) decreasing the number of lateral braces between the arch ribs (the main bridge arranges only 4 little lateral braces with the diameter of 800 mm) and expanding the traffic place, as shown in Fig. 5.

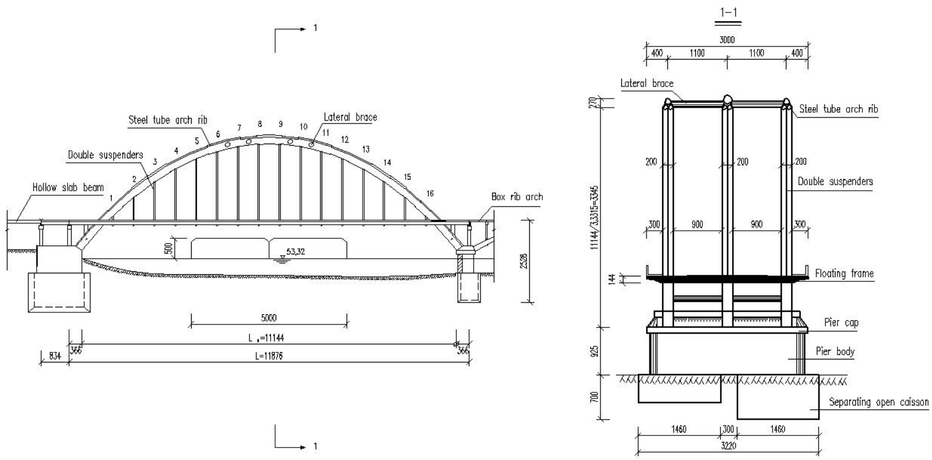

Fig. 2. *Layout of half-through arch bridge (unit: cm).*

Fig.3. *Middle joint of three-tube type.*

Fig. 4. *Closure of single arch rib.*

Fig. 5. *Closure of three arch ribs.*

2.3. Construction of upper structure

Cable-hoisting construction method is introduced into the construction of the bridge upper structure, and the corresponding arrangement is two spans with the same span of 410 m. Single steel tube arch rib is divided into six parts for precast segment assembling, and the weight of each part is less than 400 kN. Meanwhile, the construction of hollow slabs and box rib arch are also assisted by cable-hoisting construction method, and the total lifting weight is more than 400000 kN, which realizes the rapid construction and relative cheap equipment cost.

3. CONTINUOUS STRUCTURE OF CANTILEVER BEAM

With the rapid development of economy, now the volume of traffic of the bridge maybe amount to tens of thousands of vehicles one day. Meanwhile the phenomenon of the vehicle overload is increasingly severe. Therefore, the risk of simply-support deck fracture is bigger due to the overstress of the suspenders. If the continuous longitudinal girders are set between the adjacent lateral beams, on the one hand, the overload can be distributed to 2 to 3 suspenders along the longitudinal girder, which will obviously decrease the stress of the suspender, on the other hand, the longitudinal girder and lateral beam can form continuous frame, and realize the continuous bridge decks, which will overcome the crack and slippage of supporting position for simply-support bridge deck system.

In view of the conventional longitudinal girders are set below the arch rib, longitudinal girders can not keep continuous due to the hinder of the arch ribs. So a new floating system is proposed in the design of the bridge after years of study.

3.1. Floating continuous frame system

Floating continuous frame system with the length of 127 m and the width of 26.8 m is supported by 16 row suspenders and 4 row columns, as shown in Fig. 6. Among the system, the total number of the longitudinal girders are 5, and the number of lateral beams are 21. The arch ribs go through the frame, and the reserved gap width of the frame is 0.2 m. The bridge decks with the thickness of 0.28 m place in the inside of the frame, which are divided into A type (supporting in the longitudinal frame and the number 54) and B type(supporting in the lateral frame and the number 80). All bridge decks are connected by reinforced concrete wet joint.

3.2. Construction procedure

The construction of floating continuous frame system is as follows:

1) Fabricating rectangular small frame. The small frame consists of two short lateral beams (the length is 3.6m) between the adjacent suspenders and the longitudinal girders on both sides(the length is 5.0 m), and the corresponding size is 3.6 m (width)×7.6 m (length)×(1.17~1.33 m)(height), as shown in Fig. 7.
2) Hoisting rectangular small frame. After attaining designing strength, the rectangular small frame is hoisted by cable lifting system, as shown in Fig. 8.

3) Forming the connected and long lateral beam. After hoisting in position, the bailey scaffolds are lifted onto the foot of three lateral suspenders locating the same row in order to assemble the lateral beam precast block (the length is 7.4m) between three small frames, as shown in Fig. 9. The long lateral beam will be formed when finishing the further steps, including welding the joint reinforces, casting the concrete locating the seams and tensioning the lateral prestressed tendons, , as shown in Fig. 10.
4) Forming the big frame. When 23 rows lateral beam are in position, the short longitudinal girders are placed on the bailey scaffolds, and the big frame will be formed by welding the joint reinforces, casting the concrete locating the seams and tensioning the longitudinal prestressed tendons, as shown in Fig. 11.
5) Forming the continuous bridge deck system. When the floating frame system is established, the bridge decks will be hoisted onto the frame, as shown in Fig. 12, and the continuous bridge decks system will be formed by melding the reinforce between the decks and casting the joint, as shown in Fig. 13.

3.3. Design of deck pavement

In view of the crack of the existing bridge deck in Guangdong, a new double composite deck pavement is proposed to overcome the existing withdraws, including the bottom steel fiber concrete with the thickness of 30 mm, the reinforce net with the spacing of 100 mm and the diameter of 12 mm, and the surface polyester fiber bituminous concrete with the thickness of 50 mm. Due to keeping continuous of the deck pavement, the using effect is good after opening traffic for more than 10 years.

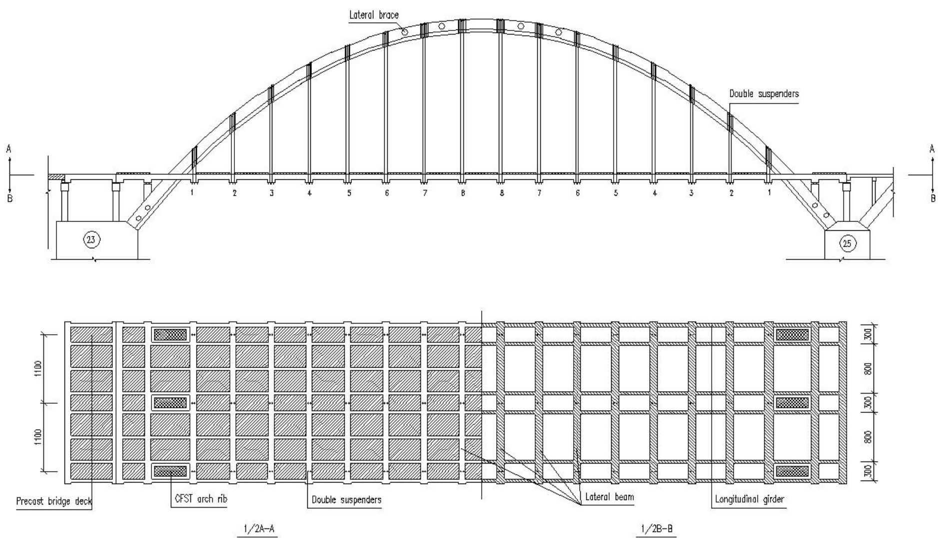

Fig. 6. Longitudinal girders and lateral beams frame (unit: cm).

***Fig.** 7. Precasting rectangular small frame.*

***Fig. 8.** Hoisting small frame.*

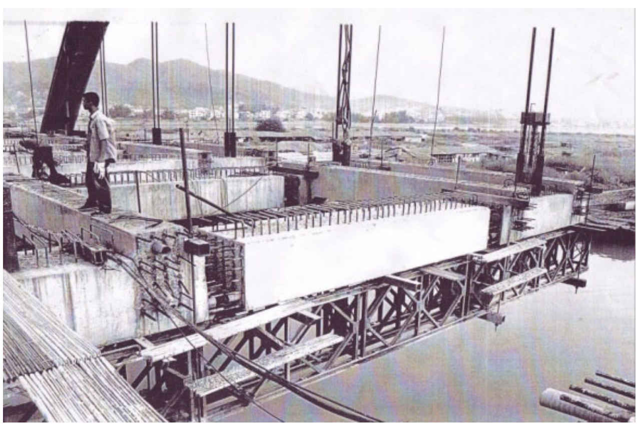

***Fig. 9.** Assembling lateral beam.*

Fig. 10. *Forming long lateral beam.*

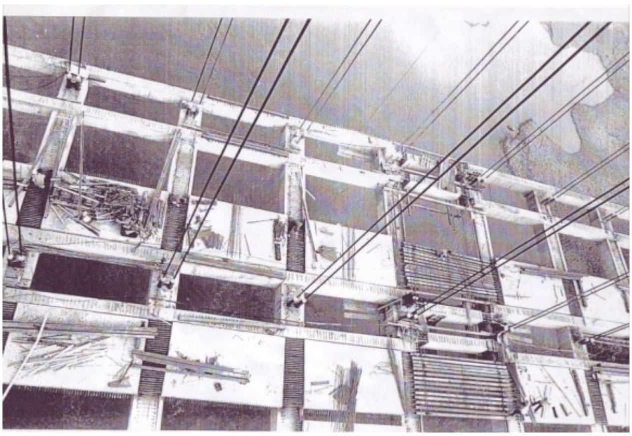

Fig. 11. *Forming the frame.*

Fig. 12. *Erecting bridge decks on the frame.*

Fig. 13. Casting the joints of bridge deck.

4. DESIGN OF SUSPENDERS AND SUPPORTS

4.1. Design feature of suspenders

Considering the fatigue damage and corrosion resulting in the fracture of the short suspenders, double suspenders in the same point are designed. In order to reduce the probability of fatigue damage, double suspenders adopt different section areas acquiring different vibrating frequency. Meanwhile, the bearing capacity of the lateral single row suspenders are decided by the dead load of adjacent spans, which can prevent the collapse of cantilever beam once single suspender is broken. Additional, the suspenders should be changed when the service cycle exceeds 30 years, and the traffic don't need to pause if changing the suspender one by one.

There have 96 double suspenders in the bridge, including 64 double suspenders on both sides and 32 double suspenders in middle. Double suspenders on both sides consist of 55 parallel wires and 61 parallel wires with the diameter of 7mm, respectively. While the middle double suspenders consist of 61 parallel wires and 73 parallel wires with the diameter of 7mm, respectively.

4.2. Design of supports

For the supports locating in the piers and abutments, GPZ is adopted. But for the supports location in the column of arch ribs, considering the need of deformation compatibility between rigid pile and flexible arch, steel ball bearing is adopted to fit the longitudinal big rotation of continuous girder. Meanwhile, in order to balance the effect of temperature expansion, automobile braking force and impact force, GJZ with the thickness of 200mm is set in the top of steel ball bearing, which solve the asymmetry deformation problem at both ends of continuous deck of single span arch bridge.

5. CONCLUSION

Baiwang bridge in Shaoguan was completed in 2004, which was the first CFST half-through arch bridge adopting floating system to realize the continuous cantilever beam. Now the bridge has opened the traffic for more than 10 years, but the quality of the bridge is very good. The new design concept reduced the probability of continuous collapse for cantilever beam, and advanced the reliability and durability of CFST half-through arch bridge in China, The results can be as reference in the same design. References

REFERENCES

[1] QIDE DAI, HAILONG TIAN., Fabricating of CFST arch bridge on site, *Journal of China & Foreign Highway*, Vol. 25, No. 4, 2005, pp. 106-108.

[2] BAOCHUN CHEN, *Design and construction of concrete filled steel tube arch bridge*, China Communications Press, Beijing, 1999, pp. 286.

[3] GUANXING SHANG, LIN TONG, JIANHONG HUANG, RUDONG ZHAO, Introduction to Design of Three Beam and Arch Combined Bridges, *Central South Highway Engineering*, Vol. 28, No. 2, 2003, pp. 98-102.

[4] ZHIFENG YANG, *Design of a new CFST arch bridge*, *Hunan Communication Science and Technology*, Vol. 33, No. 3, 2007, pp. 78-81.

[5] XIAOJIA LIU, RUDONG ZHAO, A new idea of design and construction of CFST arch bridge, *Hunan Communication Science and Technology*, Vol. 31, No. 4, 2005, pp. 93-96.