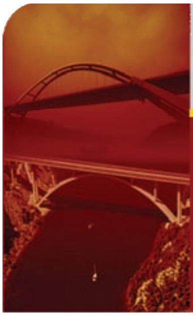

FUZHOU UNIVERSITY

Chinese-Croatian Joint Colloquium
LONG ARCH BRIDGES

Brijuni Islands, 10-14 July 2008

WANXIAN LONG SPAN CONCRETE ARCH BRIDGE OVER YANGTZE RIVER IN CHINA

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Key words: Bridge, concrete arch, design, construction, selfshoring, long span

Abstract: *The Wanxian Yangtze River Bridge is a reinforced concrete arch with a main arch span of 420m. An innovative self-shoring staged construction method was developed to build this bridge across the Yangtze River at Wanxian, in Chongqing, China. The method uses a steel tube truss arch constructed by the conventional cantilever erection technique. This paper briefly presents the design and construction of Wanxian Yangtze River Bridge.*

1. INTRODUCTION

The Yangtze River is the third longest river in the world. The 600kM reservior section of the Three-Gorge Hydro-electric Power Station is well known all over the world for its torrent, cliffed banks and magnificent scenery on both sides. Wanxian Country, having a histroy of more than 2000 years, is located at the intermediate area of the Three-Gorge reservior, and is an important part on the upper reach of the Yangtze River. With the rapid ecnomic development and the construction of Three-Gorge Dam, it is quite urgent to build a bridge crossing Yangtze River in Wanxian.

The Wanxian Yangtze River Bridge is just located 7kM away from the city. It is a record-breaking design for a reinforced concrete arch bridge with a main arch span of 420m. It was completed in July 1997(Figure 1). The total length of the bridge is 856 meters. The north approach consists of eight simple spans of 30.7 m and the south approach consists of five simple spans of 30.7m (Figure 2). The deck is 24m wide, carrying four-lane traffic and two pedestrian sidewalks. The achievement of Wanxian Yangtze River Bridge is not only the outstanding design, but also the innovative self-shoring staged construction method.

Figure 1: Wanxian Yangtze River Bridge

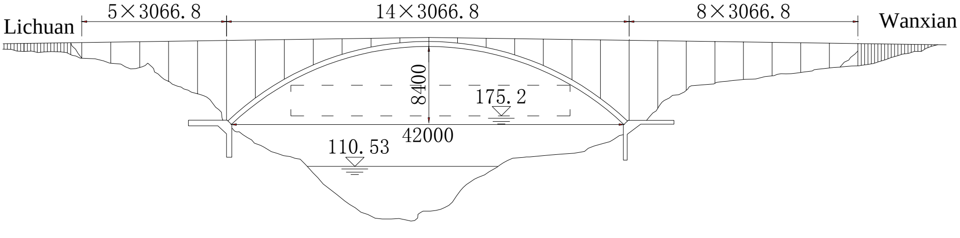

Figure 2: Elevation of the Wanxian Yangtze River Bridge(unit: cm)

2. DESIGN

The design, with its large reinforced concrete main span arch, was chosen to avoid the need for underwater foundations and extremely tall piers. In the feasibility study, various bridge types with different span lengths were examined: suspension bridge, steel arch bridge, PC rigid frame bridge, steel and PC cable-stayed bridge, and the RC arch bridge. Take the economic factor and the geographical condition for construction into consideration, the RC deck arch with a 420m clear span and 84m rise out of 18 designs was finally considered the best solution. Evidently, such long span concrete arch would be a challenge for both the desiners and engineers, it was a great step for the span of arch bridge.

1.1 Main arch

The arch axis is a catenary curve with a rise-to-span ratio of 1/5. The arch ring is three cell box section, 7.0m high and 16.0m wide, with 40cm upper and lower flanges, as shown in detail in Figure 3. A concrete filled steel tubular arch truss frame was served as the rigid skeleton, weighing 2160t. It was designed mainly to support the weight of the concrete arch during construcion. The tubes were filled with C60 concrete with an ultimate strength of 60Mpa.

The arch truss frame, 6.45m deep and 15.2m wide, is composed of five trusses spaced 3.8m from each other. The seamless steel pipes is 16mm thick and 402mm in diameter. Vertical struts and the diamond-shaped diagonals of the web members, as well as all lateral and cross bracing, are made of steel profiles. There are totally 10 tubular chord members for the arch ring.

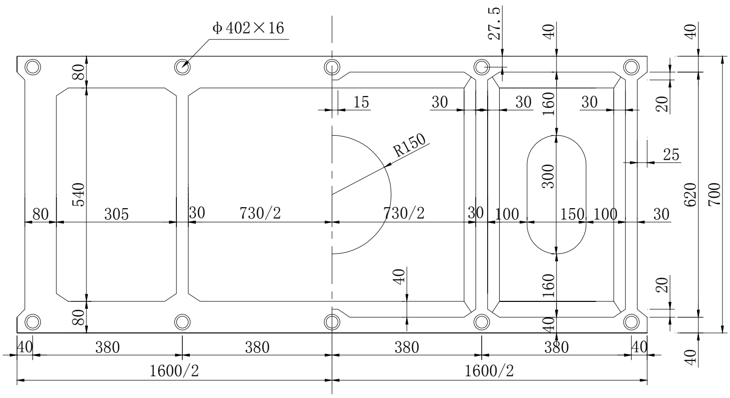

Figure 3: Cross section of arch ring (unit: cm)

1.2 Substructure

Since geological conditions at the abutments were not adequate to support the arch structure by traditional foundations, the vertical and horizontal reactions were designed to be resisted by vertical piles under the abutments and massive horizontal blocks behind them, without considering the inclined bearing capacity of the abutments themselves.

3. CONSTRUCTION

For such long span arch, if the conventional cantilever erection method were used, crane lifting capacity as well as number of precasted units would be very high. In addition, a very large temporary balance tower system would be required to maintain the balance and stability of the massive cantilever arch rib. For these reasons, construction cost of the arch would be much higher than that for other design alternatives.

To reduce the cost and complexity of construction, a new selfshoring construction method was developed. The method uses a CFST truss frame by the conventional cantilever technique. This steel tube frame performs the dual role of arch falsework and arch main reinforcement. After the steel tube truss frame is completed, concrete is pumped into the steel tubes to increase the capacity of the truss frame system. The stiffened truss frame is then encased by subsequent concrete placements to become the main reinforcement of the completed arch section. Once the reinforced concrete arch is in place, the columns, spandrel beams, and deck system are constructed. The self-shoring staged construction method leads to reduced weight, incorporation of shoring into the final load-carrying structure, and savings in construction equipment and labor.

The self-shoring construction method has not been used at such a large scale, and no previous experience could be used. However, the experience gained in building composite concrete and steel arch bridges in China in the past two decades provides sufficient information and knowledge for engineers to deal with this challenge.

3.1 Erection of the Steel Tubular Arch

Each steel tubular arch was divided longitudinally into 36 sections by 12.9m in axial length and weighing 60t. All sections were fabricated and assembled at a shipyard about 200km upstream from the bridge and the shipped to the site. The arch was erected mainly by cable crane with the help of temporary stays and hanging stays (Figure 4). After each section was erected, the temporary stays had to be used for the next section to be erected and cantilevered. Strong hanging stays were used for each three sections, and then the two former temporary stays could then be removed. There were all together twelve hanging stays that supported the weight of the arch truss frame during its erection, which were removed after the truss frame was closed.

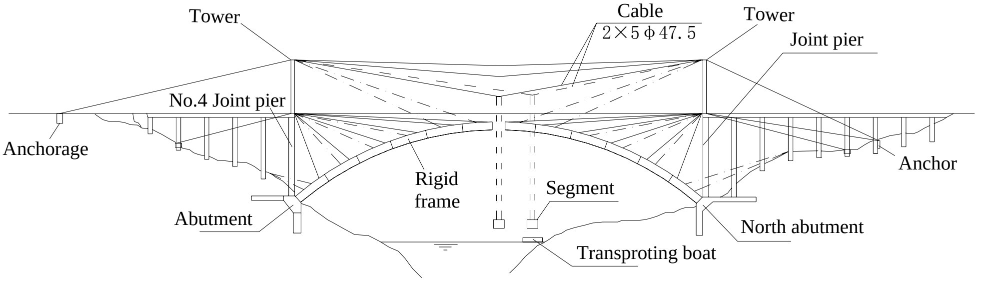

Figure 4: Erection procedure of steel tubular arch ribs

Figure 5: Erection of segment

Figure 6: The truss frame

After the steel tubular arch ring was closed, concrete was pumped into the tubular steel chords, resulting in very stiff composite arch structure as the fundamental structural system to support the weight of the wet concrete during casting. Figure 7 shows the procedure for concrete pumping of steel tubes.

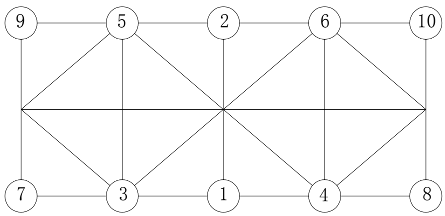

Figure 7: Procedure for concrete pumping of steel tubes

3.2 Concrete Placement

The primary emphasis was on the concrete placement process with the goals of eliminating premature yielding of the steel tubes and reducing the tension stresses in the concrete layers. This control was established by monitoring the stresses and deflections at selected governing sections.

In the longitudinal direction, each arch strip is divided into six working sections and each working section is subdivided into 4–12 segments depending on the maximum concrete volume allowed for each placement. Concrete placement was required to be simultaneous in all six working sections starting from the first segment, with only a halfsegment deviation permitted.

Each time a new concrete lift gains strength, the stiffness and capacity of the cross section increases so that the weight of each subsequently placed lift is carried by the steel tube frame and the preceding concrete lifts. The stress distribution in the steel and concrete depends on the selected construction sequence.

A study was conducted to select a concrete placement sequence that would lead to a better load distribution, minimized deflection, and minimized steel requirements, without allowing premature yielding of steel truss frame. As a result of this study, an eight-stage erection scheme was selected. The subdivision of the arch for concrete placement is shown in Figure 8. Figure 9 is the site of concrete casting.

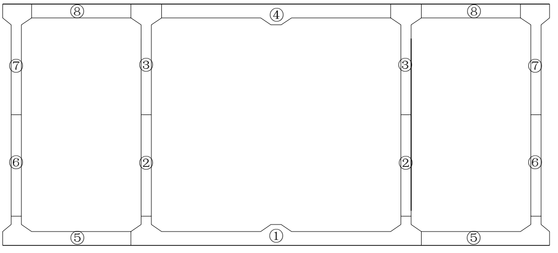

Figure 8: Working subdivision for concrete placements

Figure 9: Casting site

3.3 Construction of Spandrel Structures

All spandrel columns and deck structures were constructed by conventional methods. Columns were designed as thin-walled RC box structures, and the bridge deck was composed of ten post-tensioned T-shaped girders. All the spandrel structures were constructed in the same manner as the approaches for the sake of visul unity and simplicity of construction. Figure 10 shows the construction of deck system.

Figure 10: Working subdivision for concrete placements

4. CONCLUDING REMARKS

After 3 years' construction, Wanxian Yangtze River Bridge was open to traffic in June 1997. The innovative techniques developed in this bridge are great achievements for bridge engineering. It still keeps the world record for concrete arch bridge up to now.

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