Xiakou Xiangxi River Bridge structure design

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Abstract: Xiakou Xiangxi River Bridge is located in the upstream of the Three Gorges reservoir area. It is a (90+238) m single tower, Leaning Tower central cable surface mixed beam cable-stayed bridge. Its main span adopts a cross the river to meet navigation and flood control needs. The main concrete beam and the steel box girder of the main span are of large-angle inclined web box section with cantilever flange. The steel and mixed surface is at 11.05m across the bridge tower. The full width of the bridge deck is 25.5m. This bridge adopts the oblique "pipa" shaped main tower, the height of the main tower is 126m, composed of the upper tower column, the lower tower column, diaphragm and so on. The tower body deviates from the vertical surface of the bridge by 10° and leans towards the bank side. The foundation of the main tower is an integral pile foundation of the pile bearing platform. 2×17×2 high-strength parallel steel wire stay cables are used to arrange the fan-shaped space cable surface.

1. Introduction
Xiakou Xingxi River Bridge is significant traffic-control engineering which aims for improving provincial and national freeway network layout for local place, solving the problem of traffic congestion, making effort to build a tourism distributing center connecting The Three Gorges and the Shennongjia. The bridge located about 2 kilometers downstream of Xiakou Country, Xingshan Town, Yichang city, Hubei Province. The left bank links Quxia Road and S312 Provincial Road, the right links s255 Provincial Road. The Xingxi River Bridge is 358-meter-long and 25.5-meter-wide, which includes the main bridge and the approach. The main bridge is (90+238) meters single tower and leaning tower central cable surface mixed beam cable-stayed bridge. The bridge is in the Quaternary strata, which is mainly the holocene slope residual gravel soil. The thickness of the gravel-soil is bigger in abutment. The basement strata are mudstones and limestones. In the position of the bridge, the wind direction is always south west all those years and in the autumn and winter the wind direction would switch to northeast. The wind speed is 1m/s and the maximum speed can reach 34m/s. The layout of the main bridge, refer Fig.1.
2. General layout
Xiakou Xiangxi River Bridge adopts single-tower and Leaning Tower central cable surface mixed beam cable-stayed bridge, span layout is (90+238+2×15)m, side span is 90m concrete box girder with integral section, main span is 238m steel box girder with integral section, 2×15m is two-hole cast-in-place box girder. The overall structure is the consolidation system of tower, pier and beam, and 7.85m steel-concrete joint section is set at the connection of main beam and side span. The stay cables are arranged in a space sector with a double cable plane in the center, 2m in the transverse direction, 12.8m in the longitudinal direction and 4m in the side span. There are altogether 2×17×2 high-strength parallel steel stay cables in the whole bridge.

3. Structural design of main bridge
3.1. Superstructure
The longitudinal slope of the bridge deck is 1.0% one-way downhill. Both the concrete main beam and the steel box girder of the main span are box section with cantilever flange, and the steel mixed joint surface is at 11.05m of the bridge tower.

The full width of the bridge deck is 25.5m: 1.5m sidewalk+0.5m guardrail+0.5m hard shoulder+(3.75+3.5)m carriageway+0.5m hard shoulder+0.5m guardrail+3.0m Central Boussu District+0.5m hard shoulder+(3.5+3.75)m carriageway+0.5m hard shoulder+0.5m guardrail+1.5m sidewalk.

3.2. Supporting system of main bridge
The overall structure is the consolidation system of tower, pier and beam. The middle tower column, main tower pier and concrete main beam of the bridge tower are consolidated in one body; the pier top of No.0 abutment and main span transition pier is provided with vertical support (longitudinal activity) and transverse seismic block.

3.3. Construction and foundation design of main bridge
3.3.1. Foundation of main tower
The foundation of the main tower is an integral pile cap with a size of 17×26×7.5m and 15 bored piles with a diameter of 2.2. The pile foundation is rock-socketed pile. The outer layer of pile foundation is provided with a permanent steel guard barrel with a diameter of 2.5m and a wall thickness of 16mm.
The length of the steel guard barrel is set as 15m.

3.3.2. transition pier
Transverse double-limb solid plate pier, pier size of 2×3m (longitudinal×horizontal); The section size of the cover beam is 2.8×2.6m (width×height) with solid section; The plane size of the cap is 3.6×8.0m (shun×horizontal) and 2.5m thick. The beam section size of the cap system is 2.0×2.0m (width×height). Four D2.2m pile foundations are arranged under each bearing platform. According to the rock-socketed pile design.

3.4. Main tower design
The bridge is located in Xingshan County, Hubei province, the hometown of Zhaojun. According to the local culture, the main tower of cable-stayed bridge adopts the "Pipa" type Leaning Tower. The main tower is composed of the upper tower column, the lower tower column and the beam. The tower body deviates from the vertical surface of the bridge by 10° and leans towards the bank side. The total height of the main tower (from the bottom of the tower to the top of the tower) is 126m vertically. The tower body adopts box-shaped section and is divided into 2 sections (upper and lower of the tower column) from top to bottom.

The vertical height of the upper tower column is 53m, which is the section of single box and single chamber. The longitudinal width of the bridge gradually changes from 7m at the top to 7.524m at the bottom of the upper column, and the transverse width changes from 7.7m at the top to 13.407m at the bottom of the upper column. The thickness of the longitudinal bridge wall and the transverse bridge wall is 1.0m and 0.8m respectively. The anchoring section in the cable anchorage zone of the upper tower column is partially toothed plate and wrapped with 1cm steel plate.

The height of the lower tower column is 73m, with a single box and a single chamber section. The longitudinal bridge width changed from 7.524m to 8.2m, the transverse width curve became wider, the minimum width was 4.5m, the wall thickness of the longitudinal bridge tower was 0.8m, and that of the transverse bridge was 0.8m. The main tower is below the bridge deck and above the top of the cap. The tower beam is used for consolidation, and the prestressed steel beam is used according to the calculation Metal bellows, auxiliary grouting method for construction. Three solid wedge-shaped vertical supports with a width of 1.0 m are set on the bank side.

3.5. Main beam design
The main girder of cable-stayed bridge adopts inclined web box section with large cantilever Angle. The transverse width of box girder roof is 25.5m, the width of bottom plate is 13.7m, and the cantilever length of flange is 3.5m.

3.5.1. Concrete main beam
In order to balance the weight of the main span, the side span adopts the whole section concrete box girder and increases the section area appropriately. The top of the main beam is provided with 2% two-way transverse slope and the bottom is horizontal; The beam height at the center line of the road is 2.98m, the roof thickness at the general section of the box girder is 35cm, and the floor thickness is 50cm. In order to simplify the cable-anchored structure within the scope of the concrete beam and increase the self-weight of the main beam, a 3.2m thick longitudinal web is set in the center of the box girder. The entire box girder has a single box and double compartment section, in which the side web is 50cm thick.
Concrete box girder in bousso every 4 m set a horizontal clapboard, in the absence of cable area every 4.3 m or so set a horizontal clapboard, diaphragm plate is divided into five types: the I class for the common diaphragm plate, thick 50 cm; Class II is a beam-end transverse partition with a thickness of 300 cm; thick 300 cm; The III class for consolidation in the tower, the pier, beam transverse diaphragm, thick 100 cm; Class IV is the diaphragm at the steel-concrete joint section, 150 cm thick; The V class for the edge across the diaphragm plate near the main tower, 40 cm thick.

The main bridge concrete box girder adopts the two-direction prestressed system, and the longitudinal bridge adopts the steel bundle with a diameter of 15.2mm per share as the design of fully prestressed concrete members. In the transverse direction of the bridge, steel bundles with A diameter of 15.2mm per share are designed as part of the pre-stressed Class A members.

### 3.5.2. Steel box girder

The steel box girder adopts the whole section, the height at the center of the box girder is 3.0m, and the standard length of the sections is 12.8m. Steel box beam roof thickness 16mm, diagonal web, bottom plate thickness 14mm; The U ribs are mainly used for closing stiffening of steel box girder roof, oblique web and bottom plate, with the thickness of U ribs of top plate 8mm, oblique web and bottom plate 6mm. The central longitudinal web is solid belly, 24mm thick, with 5 channels of 14×160mm double-sided stiffening.

The standard spacing of steel box girder diaphragms is 3.20m, all of which are solid diaphragms. The corresponding diaphragms anchored with stay cables are 14mm thick. The diaphragms anchored without stay cables are 12mm thick.

### 3.5.3. Steel mixing section

The steel mixed joint section is 7.85m and it adopts the method of partially connecting and filling concrete, in which the steel lattice chamber is a box structure, the length is 2.0m, the height is 0.8m, the standard width is 1.2m and 0.8m. The 60mm round hole is cut on the steel grid web and the shear plate, and through the 20mm reinforcement and the concrete into the round hole wrapped together to form the reinforced concrete shear key (PBL key). The steel lattice chamber is connected with the steel box girder through the reinforcing section of the steel box girder and filled with concrete. In order to ensure the close combination of steel box girder and concrete box girder, there are also
prestressed steel bundles in the section. In order to ensure the free flow of concrete in the steel lattice during pouring, pouring holes are set on the roof of the steel lattice and connected holes are set on the web.

4. Conclusions
The Xiakou Xiangxi River Bridge is a cable-stayed bridge with mixed beam at the central cable surface of a single inclined tower with a span of (90+238)m+(2×15)m. The height of the tower is 126m inclination angle is 10°. The main tower cross bridge is connected with each other by ellipse, circle curve and straight line section. In the form of inclined tower and unequal span, the concrete beam pressure is arranged on the side span of the bridge, but not on the side of the larger main span steel box girder. At the same time, due to its technical and economic rationality and aesthetic superiority, this kind of small side span variable section cable-stayed bridge will become a trend in the construction of Bridges in central and western mountainous areas and across rivers, gradually. The cable-stayed bridge design of this thesis provides a reference for design and construction of the same type bridge.

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