

East bridge over Jiangxi river in Chengdu. Sichuan. China.

Spatial awareness

A spatial arch was deemed the best solution to seamlessly integrate a new landmark bridge into the park landscape and road network of a new urban development in China's Sichuan Province.

One of six bridge projects being undertaken for an industrial development zone in the city of Chengdu – the provincial capital – the under-construction East Bridge will span the Jiangxi River between a new international airport and a linear park which will run parallel to the river through the city.

An international design competition was launched for each of the bridges, and a consortium of Carlos Fernández Casado S.L. (CFC) and Shanghai Municipal Engineering Design Institute (SMEDI) presented three proposals, winning with their bid for Chengdu East Bridge. The client, Chengdu Hi-Tech Industrial Development Zone, required that the structure cross the river without the need for intermediate piers while minimising the functional and visual impact on the adjacent park and connected pedestrian routes. Original and innovative solutions were also expected because the crossing was being planned as a future landmark in the new urban environment.

Since light girders were preferable to avoid bulky solutions, arch and cable-stayed bridges came naturally as the preferred options for this span range, comments Javier Muñoz-Rojas, engineer at CFC. Ultimately a self-anchored arch structure was chosen with a main span of 152m over the river and extended on both sides with two additional spans over piers measuring 24m and 36m.

“The most relevant feature and challenge of the design was how to take advantage of the curvature of the road in plan – which has a radius of 350m and 500m – in the structural solution,” Muñoz-Rojas says. To avoid discontinuity between the road and the main structural element -the arch- , a spatial arch solution with two lateral arch ribs following the road alignment was proposed. “This type of arrangement creates a non-planar geometry of the arches and hence out-of-plane forces on them”, says Muñoz-Rojas, “CFC had already explored the possibilities of these solutions in other projects, including Galindo River Bridge and Enderlatsa Bridge, both in the north of Spain.” Different systems were used for each bridge to control the out-of-plan thrust: active forces in the first and variable inertia adapted to the transverse forces in the second.

For the East Bridge, a new option was explored. The problem was controlled with the help of the transverse bracing between the arch ribs. The result is that the warped arch and its transverse bracing configure an efficient spatial work system avoiding large transverse bending moments in the arches. Deck girder stiffness and the inclined hangers also contributed in this structural response. Compared with a straight bridge, the structural

performance is more complex since the transverse bracing is not only necessary to resist the horizontal actions caused by wind and/or seismic activity as in planar arches, but also plays an important and active role to distribute the out-of-plane forces between the two arches under any load case.

Additionally, the transverse bracing is not planar but slightly curved in vertical to create a “vault” effect over the deck and provide a more attractive end result. “This creates dynamic and attractive perspectives both for the pedestrians and for the drivers, turning the crossing of the bridge into a kind of special experience under a lattice roof,” explains Muñoz-Rojas. The transverse bracing uses tubular steel pipes, creating many intersecting joints across the bridge. “How to solve the static and fatigue safety problems of these intersecting joints has become the biggest challenge for the design and the construction,” he highlights. The conceptual design and its structural validation during the tender stage was done at CFC with Sofistik. A full 3D FEM model was prepared combining beam elements for the arch and the girder steel grid and shell elements for the concrete slab. The analysis included a preliminary non-linear analysis to evaluate the response of the arch and its sensitivity to instabilities due to its non-planar configuration. The design of the joints between the arch and the transverse bracing was evaluated with the simplified formulae of tubular joints.

Chinese authorities and designers were not very familiar with the tubular joints in bridges as proposed for the transverse bracing connections. Accordingly, the initial solutions were discussed with the SMEDI team. As a result additional internal plates were introduced to provide the tubular joints with extra-capacity due to the non-planar geometry.

Some details were also discussed to adapt the initial proposal to solutions frequently deployed on Chinese Bridges. The most relevant was the modification of the initial composite concrete-steel girder to a pure steel solution with an orthotropic deck. As a result, the final design for the 50.2m-wide deck comprises two main longitudinal box girders connected with transverse beams supporting an orthotropic deck. Each box girder will carry three lanes of road traffic.

The detailed design was developed by SMEDI lead by Mr Yue Guinping, Chief Bridge Engineer of the company, Ms Huang Hong, Vice Chief Bridge Engineer and Mr Ying Tianyi, Project Director of the Chengdu Bridges with CFC acting as advisor. The software for the general analysis was done with Midas Civil, Ansys and Catia.

During this phase of design, SMEDI carried out FEM analysis with solid elements to verify the most demanded X and K joints. The analysis was complemented with scale lab tests of some singular T nodes in the facilities of the Tongji University in Shanghai with satisfactory results.

Furthermore, minor changes were introduced to simplify construction and erection, including

- Details of the stiffening elements of the orthotropic slab to adapt it for local uses;
- Adjustments to circular chamfers in the longitudinal main girders;
- The geometry of the openings between the pedestrian and the vehicle areas;
- Detailing of the hanger anchors in the arch; and
- Adjustments in the arch-cross sections

In terms of user experience for pedestrians and cyclists, one key area of focus during design was to ensure that road traffic did not impinge journeys across the bridge. “The proximity of traffic areas on long crossings turns the walk into something definitively unpleasant,” comments Muñoz-Rojas. “On the East Bridge, a solution was applied to create independent areas for each of the mobility options, pedestrian/bicycles and vehicles. The former two

modes of travel are placed at either side of the two girders supported by transverse cantilevers." The bridge's 36 hangers anchor at deck level outside the traffic areas, which also creates a physical barrier and increases pedestrian comfort.

Reinforcing this buffer is planting along the length of the bridge between the hangers and cycle/pedestrian lanes, and the vegetation helps create continuity between the bridge and the parkland. The experience of pedestrians walking under the bridge along the riverbank has been carefully considered as well by creating numerous openings in the deck which alternate with the sections of planting to allow for natural light to pass through, avoiding a tunnel effect and dark areas under the structure.

Construction has been under way since _____, with deck and arch erection using a conventional construction system with temporary supports and shoring. The deck, girder, arch and stiffening tubular elements have been fabricated in the facilities of Jiangsu Huning Steel Structure & Machinery, which participated in the construction and installation of the so-called Bird's Nest stadium of the 2008 Beijing Olympic Games. The orthotropic deck and arch weigh in at 470kg and 170kg per square metre, respectively, while the entire bridge weighs some 7,770t.

Steel fabrication is complete, and according to Fernández, cutting and welding the stiffening intersecting joints of the tubular sections has been one of the biggest challenges of construction to date, as well as fabricating spatial bending and torsional arch elements from oblate circular sections of large-size and thick high-strength steel. Meanwhile, virtual assembly using _____ has been used to enhance efficiencies on site, avoid clashes and enhance safety.

Difficulty of the control during the assembly.

Also finished are the piers and foundation works, and erection of the steel arch structure over temporary supports has begun. According to the project timeline, works should be finished in the first quarter of next year, making East Bridge the first of the six bridge projects to be concluded.

General Information:

Client: Chengdu Hi-Tech Industrial Development Zone

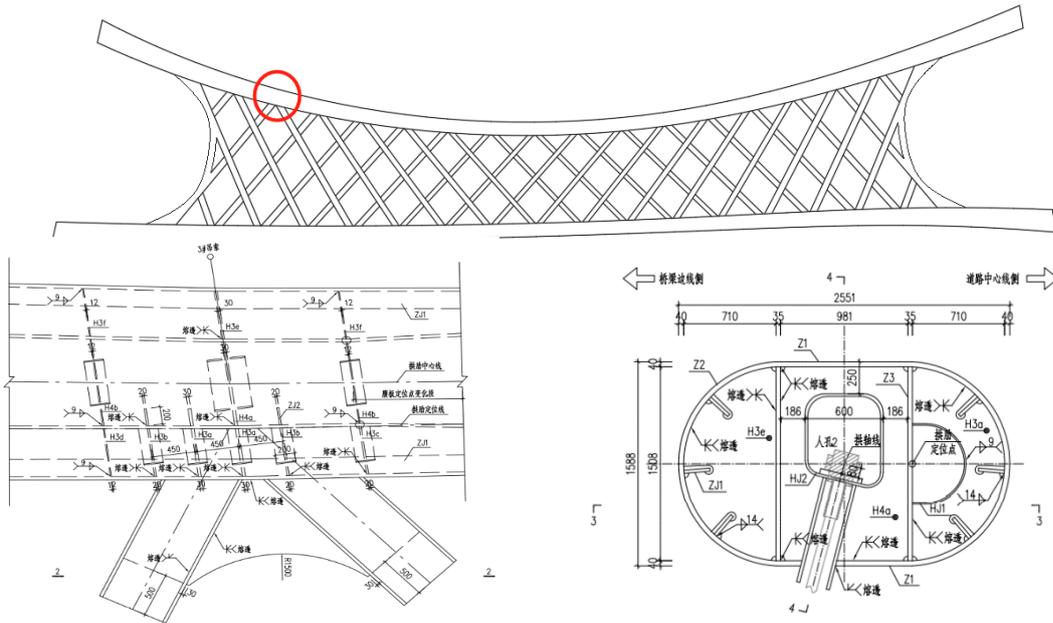
Design: CFC&SMEDI (Carlos Fernandez Casado SL/Shanghai Municipal Engineering Design Institute Group CO.,LTD.)

Main contractorConstruction: Sinohydro Bureau 7 CO.,LTD.

Steel fabricator: Jiangsu Huning Steel Structure & Machinery CO., LTD.







(a) K型节点

