TAIZHOU THREE-TOWER SUSPENSION BRIDGE — Innovation Description

Taizhou Bridge is the world's first suspension bridge to feature three towers and two long main spans rather than the conventional two tower suspension bridge with one long main span. Opened to traffic in November 2012, the bridge has far-reaching implications for long span bridge technology worldwide and will serve as a model for the next generation of water crossings requiring ultralong spans. The Bridge spans the China's Yangtze River as part of a new, $1.5-billion, 62 km freeway linking the cities of Taizhou, Yangzhou, Zhenjiang, and Changzhou The freeway network is intended to serve as a catalyst for economic growth in eastern China. The suspension bridge carries three lanes of traffic in each direction on a 33 m wide deck, featuring not one but two 1,080 m main spans and side spans of 390 m. The 203 m unique tall central tower between the two main spans comprises two parallel inverted Y frames in elevation. Constructed of steel, the tower is founded on a 58 by 44 m caisson. The 183 m tall towers located at both ends of the bridge are concrete structures, each founded on 46 friction piles 2.8 m in diameter. The river at the bridge site is some 2.1 km wide, and the riverbed has channels on each side. The channel has a W-shaped cross section at the bridge alignment, the deeper channel having a depth of 30 m and the other a depth of 17 m. The banks of the river are Yangtze alluvial plains with a thick cover layer of soil. Bedrock is generally 190 m or more down.

All elements of the planning, design, and construction of the bridge were aimed at minimizing adverse environmental effects. In fact, the three-tower, two-main-span suspension design was chosen for environmental reasons, for by minimizing the number of piers in the water, it would have only a slight effect on river hydraulics and river ecology. Furthermore, its two main navigation channels would be wide enough to facilitate ship movements and encourage the development of port facilities in the region.

As this was the world's first attempt to design and construct such a bridge, substantial research and development efforts were indispensable for ensuring safety and proper performance. The structural behavior of a three-tower continuous suspension bridge system is different from that of a conventional two-tower suspension system, particularly with respect to the erection of the main cable and main girder and the control of bridge geometry. The design also had to ensure that, irrespective of loading conditions, the cables would not slip as they passed through the saddles. Conflicting demands on the central tower stiffness therefore arose: a flexible central tower helps prevent cable slip but is ineffective in controlling girder deflection, whereas a stiff central tower makes it difficult to prevent cable slip.

The north and south cable anchorages were constructed as gravity anchorages on caisson foundations. The caissons measure 68 by 52 m in plan, the one on the north being 57 m deep and the one on the south having a depth of 41 m. The caisson beneath the central tower was located in the middle of the river and founded in the riverbed at 70 m deep, resulting in the deepest underwater bridge caisson construction ever achieved. Thus a sophisticated control system, together with a high-precision Global Positioning System methodology, was necessary to mitigate oscillations induced by wind or current. In an effort to meet its challenges, the Taizhou Bridge Project set five world records. In addition to being the first three-tower, two-span suspension bridge to have long spans and the first bridge to have such a deep underwater caisson foundation for its central tower, the crossing features the tallest central tower (203 m) and the longest (3,110 m) main suspension cables. Furthermore, the construction saw the first concurrent erection of two long suspended deck girders in an integral suspension bridge system.

The Taizhou Bridge suspension system represents an improvement over conventional two-tower suspension systems in that additional vertical support is provided by the third tower; this reduces the internal forces in the main cables and anchors. But the design presented new issues. Under the most adverse loading conditions, namely, a full live load on one main span and none on the other, the deflections of the deck could be significant and had to be kept within limits. The friction between the main cables and the saddles also had to be sufficient to prevent cable slip. But in meeting these two criteria, the stability and structural adequacy of the central tower also had to be preserved.

The central tower is at the edge of the deep thalweg in the Yangtze River. A caisson foundation was chosen because it would best resist seismic events and ship impacts and still be cost competitive. The caisson has an overall height of 76 m and is divided into two 38 m high halves. The lower half is a prefabricated rectangular steel shell, and the upper half is of concrete. The first part of the steel shell was fabricated onshore and then floated to the bridge site, where construction continued to its 38 m height. The steel shell was precisely set at its permanent location by a position control system and was sunk into the riverbed by flooding it with water. The placement had to be accurate within 500 mm in plan, 1/150 in gradient, and 1 degree in torsional angle. Once in position, the chambers of the steel shell were filled with concrete. Underwater concrete casting was used to complete the construction of the central tower's foundation.

The Taizhou Bridge project is a singular accomplishment rich in its contributions to modern bridge engineering. Its strategic geographic location makes the crossing a vital economic link connecting Jiangsu's growing cities. With this link as a catalyst, enhanced growth will be brought to the Yangtze River delta region and, indeed, to all of eastern China.

The bridge won the Institution of Structural Engineers Award for Highway or Railway Bridge Structures and its top prize, the Supreme Award for Structural Engineering Excellence. The Taizhou Bridge was one of five finalists for ASCE's 2014 Outstanding Civil Engineering Achievement Award.

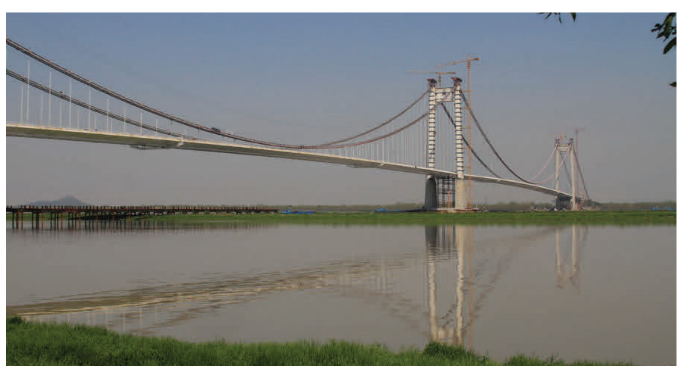
Primary sources: "Stretching the Limits," *Civil Engineering*, ASCE and "Taizhou triple," *Bridge Design and Engineering*

TAIZHOU THREE-TOWER SUSPENSION BRIDGE

Central tower foundation

Central tower base from side

Placing deck panels



Nearing completion