Long standing

Chongqing features China's span giants

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To learn about the bridges of Chongqing, we first need to know a few facts about China.

China's total land area of 3.7 million sq miles is about the same as the U.S. However, its total arable land of about 0.55 million sq miles is less than the U.S.'s 0.68 million sq miles. Of the U.S.'s 317 million people, only 2.4% are farmers. Compare that to China's population of 1.36 billion, about 80% of whom lived on farms in 1980. Some quick math reveals that available land per Chinese farmer has been about 5.7% of that per U.S. farmer. No wonder Chinese farmers have been extremely poor.

To improve the standard of living of its rural population, China launched aggressive urbanization policies aimed at leaving only 20% of the population in farming to ensure farmers have sufficient land. This equates to transforming about three-quarters of the Chinese farming population to urban dwellers—a staggering 810 million people, or more than twice the total U.S. population. By the end of 2013, about half of this goal had been met, with about 420 million people moved from farm to city. To facilitate this ongoing migration, China must expand existing urban centers and develop new ones, which will require new infrastructure like roads and bridges.

Chongqing has an area of 32,139 sq miles, a population of 32 million and hilly terrain intersected by several large rivers including the Yangtze and Jialing. Over the last 30 years, this major municipality has built more than 10,000 bridges, including two world-record spans: the 1,811-ft Chaotianmen Bridge, the world's longest span arch bridge; and the 1,083-ft Second Shibanpo Bridge, the world's longest span girder bridge. That is why Chongqing is generally recognized as the "Bridge Capital" of China. Here are several recent bridge projects worth noting in this rapidly developing region.

Fact Finder

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Jiayue Bridge over the Jialing River

The Jiayue Bridge is a signature structure that crosses the Jailing River about 295 ft above normal water level and connects the new urban center Yuelai with its surrounding areas. The Chongqing Waterway Department determined that the main span of the bridge had to be at least 820 ft, which made a box-girder, arch or cable-stayed bridge all feasible. After careful studies, a partially cable-stayed girder bridge was selected, which is similar to an extradosed bridge but with slightly taller towers. This results in higher efficiency from the stay cables, which can carry a larger portion of the weight of both the heavy girder and the live load.

Bridge-type selection was the result of aesthetic considerations. Because the girder is so high above water level, two tall towers above the deck would have been visually disproportionate to the relatively minor main span length. Simple vertical towers also would have appeared too plain and stark, not in harmony with the bridge's natural environs. The final configuration of the towers has a streamlined shape, with the lower tower legs tapering from the bottom up to the girder level, and columns above the deck inclining outward. The two legs of the lower portion of the towers are connected by a cross strut, providing rigidity and increasing their ability to resist higher ship impacts.

Not only do the inclined tower columns offer bridge users panoramic views, but they also create a widening effect that breaks up the monotonic appearance of the tall towers. They also resemble a pair of open arms that symbolically welcome visitors and local residents. Additionally, the harp-cable arrangement gives the bridge a clean, delicate profile.

The cross section of the girder is a single-cell box. The bridge carries six lanes of traffic and two pedestrian-and-bicycle paths directly beneath the roadway wing slab. If the roadways and paths were placed on one level, the deck would have been too wide, making the box girder less efficient. Because the 92-ft-wide deck is still quite wide, crossbeams were used to support a uniform-thickness deck slab. The crossbeams (i.e., ribs) are under the wing slab so they could be made as deep as necessary to achieve proper efficiency.

Chongqing also is referred to as one of the three "ovens" of China, indicating how hot it can be in the summer. Placing the pedestrian and bicycle paths underneath the wing slab of the upper deck offers refuge from sun and rain, as well as providing a narrower, more structurally efficient bridge deck.

The steel pathways are suspended from the crossbeams on one side and attached to the web wall of the box girder on the other side. Pedestrians and cyclists can cross from one side to the other by using the open space underneath each end span. In addition, the walls of the pathways are available for local art exhibitions.

The box girder has a crossbeam at each stay location, with the cables anchored at the outer ends of the crossbeams. Transverse prestressing tendons in the crossbeams carry the vertical components of the cable forces into the box section. Transverse prestressing also is applied to the deck to facilitate the transfer of the horizontal component of the cable force from the edge of the deck to the entire bridge deck and further to the entire cross section of the girder.

The design called for a cable system that could be tensioned and/or replaced strand by strand. These cables are made up of epoxy flofill seven-wire strands. At the tower end, the cables are anchored to a steel box, which is encased in the concrete tower walls. Shear studs are used to transfer the force in the steel box to the surrounding concrete.

To compensate for the narrow appearance of the girder, a diamond-shaped tower was selected for the Caijia Bridge to provide a more solid, substantial appearance.

Caijia Bridge over the Jialing River

The main bridge of Chongqing's Caijia Bridge comprises five spans totaling 2,100 ft, with shorter end spans to compensate for the bridge girder's proximity to the ground. Carrying two transit tracks, the entire structure has a length of 4,100 ft. To compensate for the narrow appearance of the girder, a diamond-shaped tower was selected to provide a more solid, substantial appearance.

The bridge girder crosses more than 328 ft above the Jialing River's normal water level, as water levels at this location can rise nearly 100 ft during flood seasons. That made it crucial for the towers to have sufficient resistance capacity against possible vessel impacts at various water levels. The two legs of the lower tower portions are connected to form a larger box cross section, which extends above the highest high-water level. Not only is the lower tower portion much stronger for resisting possible impacts, but the diamond-shaped configuration also complements the beautiful Jialing River Valley surroundings.

For aesthetic reasons, as well as to streamline water flow, the piers of the Shibanpo Bridge were placed adjacent to the old bridge piers, necessitating the same span arrangement. After extensive study, the Chongqing Waterway Bureau decided that the pier between the existing main navigation channels must be removed. Consequently, the main span of the new bridge is about 1,083 ft.

Shibanpo Bridge over the Yangtze River

The new Shibanpo Bridge is located upstream of and parallel to an older bridge. The distance of the centerlines of the two structures is 82 ft. The width of the older bridge is 69 ft and the width of the new bridge is 62 ft, with a clear distance of only 16.4 ft between the edges of the two decks.

For aesthetic reasons, as well as to streamline water flow, the piers of the new bridge were placed adjacent to the old bridge piers, necessitating the same span arrangement. However, the older bridge's 571-ft main span is tight for today's navigation needs, even without the new structure. Construction of the new bridge with the piers adjacent to the old piers would have significantly increased the width of obstruction in the transverse direction, creating a tunnel effect that would have severely hindered the maneuverability of river traffic. After extensive study, the Chongqing Waterway Bureau decided that the pier between the existing main navigation channels must be removed. Consequently, the main span of the new bridge is about 1,083 ft.

With the two superstructures located so close together, the most suitable bridge types for a main span of this length, cable-stayed or arch, would not have worked aesthetically with the existing box-girder bridge. The owner requested that the new bridge also be a box-girder bridge, if technically possible. The span length made the new structure longer than all existing box-girder bridges in the world, taking its design beyond existing experience in either steel or concrete girder bridges.

Norway had built several long-span concrete-box-girder bridges. This includes the 987-ft Stolmasundet Bridge, which was completed in 1998 and utilizes lightweight concrete in the middle portion of the main span and normal-weight concrete in the rest of the structure. Such a hybrid system makes sense, as reducing the weight of the middle portion is effective in reducing the bending moment in the bridge. However, the aggregate for the lightweight concrete had to be imported from the U.S., which was economically unfeasible for the Shibanpo Bridge. The long-term deflection due to creep and shrinkage of concrete in such a long span also would be hard to control. Therefore, a steel box girder was used for the middle 338-ft section of the main span.

The steel box girder, fabricated more than 600 miles downstream in the city of Wuhan, was designed as a barge with both ends closed temporarily. Towed through the Three Gorge Dam to Chongqing, it was rotated 90°, positioned under the main span and lifted to its final location with strand jacks. Because the Yangtze River is the area's main waterway, only 12 hours was allowed for the lifting operation.

Looking forward

Over the last 30 years, China has built more miles of highways and superhighways than the U.S. Whenever such a highway hits a river or a valley, a bridge will be needed to span the obstacle. With its ongoing farm-to-urban-area migration plan, China will continue building more highways over the coming years. It can be anticipated that more bridges will be needed and built as a result. **R&B**

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For more information about this topic, check out the Bridges Channel at www.roadsbridges.com.