The Development of Infrastructure and Technology for Steel Bridges in Taiwan

BY

JAW-LIEH, WANG ¹
DZONG-CHWANG, DZENG ²
ENG HUAT, TEO ³
PENG-CHI, PENG ⁴

SYNOPSIS

Steel bridge is for rapid construction or lighter weight required, especially for long span bridge, which is used in steel box girder bridge, cable-stayed bridge and suspension bridge. There are many kinds of steel bridge design and construction in Taiwan, including long span box girder bridge, steel arch bridge and cable-stayed bridge.

Some steel bridge design will be introduced in this article, from plate girder bridge, steel box girder bridge and specialist style bridge, as well as the development of technology of steel bridges in Taiwan. Moreover, two special bridge project in Taiwan will be introduced. Once is “The Widening Project from Wugu to Yangmei”, which has won the 2015 IRF Global Road Achievement Awards (GRAA) design award. The other is “Shezi cable-stayed Bridge”, which has won the 2012 Structural Technology Award of Taiwan Structural Engineers Association.

Keywords: Steel bridge, Box Girder, Cable-Stayed bridge, Widening project, Cantilever Method Rotating Method.

1. President, CECI Engineering Consultants, Inc., Taiwan.
2. Assistant Vice President, Department of Structural Engineering I, CECI Engineering Consultants, Inc., Taiwan.
3. Technical Manager, Department of Structural Engineering I, CECI Engineering Consultants, Inc., Taiwan.
4. Manager, Metallurgical Department, Dragon Steel Corporation, Taiwan.
1. FOREWORD

Steel bridge is either for rapid construction or lighter weight requirement, especially suitable for long span bridge, which is used in steel box girder bridge, cable-stayed bridge and suspension bridge. There are many kinds of steel bridge design and construction in Taiwan, including long span box girder bridge, steel arch bridge and cable-stayed bridge. The design of steel bridge will be introduced in this article, including plate girder bridge, steel box girder bridge and specialist style bridge, so as its development and technology in Taiwan. In the early time of Taiwan, steel bridges construction are made by steel plate and mostly are for railway or main connecting bridge to Taipei city.

There are various style and structural characteristics in different period of time during the development of steel bridge in Taiwan which can be simply divided into four stages. In addition, bridge types, technological developments, and different steel plate materials will be introduced, followed by the development history of steel bridges, including project steel bridge designs, box girder bridge, arch bridge, cable-stayed bridge and suspension bridge in recent years in Taiwan.

Moreover, two special bridge projects in Taiwan will be introduced as well. One is “The Widening Project from Wugu to Yangmei”, which has won the 2015 IRF Global Road Achievement Awards (GRAA) design award, and another is “Shezi cable-stayed Bridge”, which is the winner of 2012 Structural Technology Award of Taiwan Structural Engineers Association.

2. DEVELOPMENT OF INFRASTRUCTURE AND TECHNOLOGY FOR STEEL BRIDGE

Early from the Qing Dynasty, the governor Liu Ming-chuan had built a railway from Keelung to Hsinchu at the north of Taiwan, with the total distance about 106.7 km, more than 70 bridges were built up in this project, and most of them were made by wood and iron. Among them, the Keelung River Iron Bridge is known as the first railway bridge in Taiwan which has been famous from Qing Dynasty to even nowadays. This bridge was originally completed in 1890, and was destroyed in 1892 by flood. It was purchased from abroad in 1893 and is a truss bridge type iron bridge, Figure 1. This bridge lately was converted to be used as a driveway bridge since the railway has changed to the new route.

During the Japanese occupation period, starting in 1895, European and American engineering technology was started to build roads and railways. There were more than 2,000 bridges built in Taiwan before the Taiwan Retrocession Day. Most of them were steel bridges using steel plate beams and steel truss, which is applied as railway bridges.[1]
Around the 1990s, during the early Japanese occupation period, many railway bridge were built, including Badu Bridge, Fengshanxi Bridge, Yutengping Bridge, Neisaichuan Bridge, Baochanghangxi Bridge and Shiniuxi Bridge, as shown in Figure 2. After that, numbers of railway steel plate bridge were built sequentially, as shown in Figure 3.

![Badu Bridge (1898)](image1)
![Fengshanxi Bridge (1902)](image2)
![Yutengping Bridge (1907)](image3)
![New Yutengping Bridge (1938)](image4)
![Neisaichuan Bridge (1907)](image5)
![Reconstruction after Taichung EQ (1938)](image6)
![Baochanghangxi Bridge (1899)](image7)
![Shiniuxi Bridge (1908)](image8)

Fig. 2 Early steel bridge in Taiwan (about 1900s)
In addition, numbers of steel truss railway bridges were also built during that period, including Daanxi Bridge, Dajiaxi Bridge, Zhuoshuixi Bridge and Xiadanshuixi Bridge, as shown in Figure 4. Those bridge was design as a single span and mostly arranged at about 62.4m.
At that time, in order to promote Taipei city as a famous capital, four bridges crossing Xindian River, Danshui River and Keelung River were built. The bridge across Keelung River, which is using steel truss bridge, was the first generation Meiji Bridge (at the location of Chungshan Bridge in present). The bridge across the Tamsui River, which is using steel truss bridge, was Taipei bridge (now still called Taipei Bridge). The bridge across the Xindian River, which is using suspension bridge, was Showa Bridge (at the location of Guangfu Bridge in present). The bridge across the Xindian River, which is using steel plate girder bridge, was Kawabata Bridge (now called Chungcheng Bridge). Photos of those bridges are shown in Figure 5.

In the early days of Taiwan's retrocession day after 1945, since the economic environment was not good, the construction of the bridge was mainly based on retrofit. The first bridge built after retrocession day was Xiluo Bridge, which was completed in 1953. The bridge is a steel truss bridge with 62.4m span length and 31 spans in total. The substructure of the bridge was completed during the Japanese occupation, while the superstructure was imported from the United States and began installation in 1952. The another bridge, Zengwenxi Bridge, is also completed in the same year, and was the first steel plate girder railway bridge, their photos were shown in Figure 6.
Meiji Bridge (Chungshan Bridge, 1901)  
Taipei Bridge (1925)  
Showa Bridge  
(Guangfu Bridge, 1933)  
Kawabata Bridge  
(Chung Cheng Bridge, 1937)

**Fig. 5** Early time Taipei City’s famous bridges

![Xiluo Bridge and Zengwenxi Railway Bridge (1953)](image)

**Fig. 6** Xiluo Bridge and Zengwenxi Railway Bridge (1953)

After the development of Taiwan’s economy, some steel bridges with special structures were built, as shown in Figure 7. These includes Changchun Bridge and Keelung River Railway Bridge, two steel truss bridges, Taipei bridge, a steel box girder bridge, Dahan Bridge, an arch bridge, and Fuhsing bridge and Baling bridge, two suspension bridge.
After the China Steel Corporation started the production of steel plates at 1977, the application of steel bridges become more various and adopted different style of steel bridge. The Guandu Bridge, which was completed in 1983, is a 5-span continuous half-through steel arch bridge with a span configuration of $44+143+165+143+44=539$ m, as shown in Figure 8.
Due to the rapid growth of vehicles and the high utilization of land, it is difficult to carry out engineering construction in metropolitan area. In Taipei, Civil Boulevard Viaduct which goes across the city was built during the undergroundization of railway. Steel box girder was used to reduce the self-weight and fulfil the rapid construction requirement. Total length of the viaduct is about 6.8km and more than 80,000 tons of steel plate was used. The bridges are co-constructed with subway tunnels, underground shopping streets and underground parking lots, creating a lot of useful spaces, which is the longest co-structure bridge project with the underground structure (Figure 9).

![Fig. 9 Civic Boulevard Taipei City (1996)](image)

During the construction of the second freeway in Taiwan, a long span single pylon cable-stayed bridge was adopted to cross the Kaoping River. The main span of the bridge is 330m using steel deck girder, the side span 180m using concrete structure with a total length of 510m. This bridge has the longest span in Taiwan until now, as shown in Fig. 10.

![Fig. 10 Kaopingxi Cable-Stayed Bridge.](image)
After that, numbers of specialist bridge was built with steel plate. Those bridge can be divided into steel box girder bridge, arch bridge, truss bridge and cable-stayed bridge according to the structure style. Figure 11 shows four long span box girder steel bridge in Taiwan, most of them uses steel deck box girder except the Guoshing bridge, which uses RC deck instead. Figure 12 shows double deck steel box girder bridge, Figure 13 shows steel arch bridge and two of them are double deck steel arch bridges, while Figure 14 shows truss bridge, and Figure 15 shows cable-stayed bridge.

![Shuiyuan Expressway](1992)
![Choumei Expressway](2002)
![Linkou Bridge](2013)
![Guoshing bridge](2012)

**Fig. 11 Steel Box Girder Bridge**

![Shuiyuan Expressway](Huandong Bridge)

**Fig. 12 Double Deck Steel Box Girder Bridge**
Fukuo Bridge

Duming Bridge

McArther 2 Bridge

Sijih Connecting bridge

Fig. 13 Steel Arch Bridge

McArther 1 Bridge

Huandong bridge

Fig. 14 Steel Truss Bridge

New Serho Bridge

Xinfia Bridge
About the materials used for Steel Bridge in Taiwan, before 1999, are mostly American standards ASTM A36 and ASTM A572 Gr. 36 or Gr. 50. However, due to the specification for steel bridges, ASTM A709 steel plate become more common after 1999.

Among all the bridges introduced earlier, two project will be carry out due to some special characteristics in design and construction. Those two projects are the Widening Project of Wugu to Yangmei section of Taiwan’s National Freeway No. 1 and Shezi bridge, which are completed and open to traffic in 2013.

3. WUGU TO YANGMEI WIDENING PROJECT

The Widening Project of Wugu to Yangmei section of Taiwan’s National Freeway No. 1, with total length of 40 km, was completed in 2013. This widening project was aiming to improve the traffic quality and to regain the smoothness of traffic circulation on the northern end of Freeway No. 1 of Taiwan. The widening works travels along both sides of the existing freeway and 85% of the construction are viaducts, the project location map is shown in Figure 16.
Dual-way and long-span viaducts are selected as the primary construction method in this widening work from Wugu to Yangmei [1]. Sensitive geological condition is another challenge for the design work. There are sensitive geological hazard areas at the east-side of “Freeway No.1”; located at mileage 0+37k, as shown in Figure 17. According to the E.I.A. law, it is prohibited to have any constructions in this area. Therefore, it was designed to have the viaduct on both sides of existing freeway.[2]

There are two crossing bridges: Taishan crossing bridge (at kilometer mark 36k+440) and Linkou crossing bridge (at kilometer mark 39k+781) respectively. Considering the environmental limitations and existing traffic of the freeway, the planning of the crossing bridge was designed to be a long span bridge without any piers built on the freeway lanes. The weight and depth of the girder can be reduced by having a three-span continuous steel deck box girder bridge; the main span of the bridge is 216m, with two sides of the span are 135m, totally 486m. This bridge is the longest steel box girder in Taiwan and the computer simulation is shown in Figure 18.

Between Taishan Toll Station and the Linkou section, the Dakekeng River runs both adjacent and parallel to National Freeway No. 1. The new viaduct is located along the narrow road corridor between National Freeway No. 1 and Dakekeng River as shown in Figure 19.
4. SHEZI BRIDGE

The Shezi Bridge is located in the northwest of Taipei, near Beitou and Shilin area, with an inclined pylon cable-stayed bridge. This bridge has become a landmark structure with a huge pylon across the Keelung River. The cable-stayed bridge is shown in Figure 20. The Shezi bridge, which has designed as a white egret image, is designed as two-continuous span inclined pylon cable-stayed bridge. Rotating method and lifting segment up to 105m was used for the construction of the pylon, and cantilever method was used for the construction of main girder across the river.[3]

The Shezi Bridge is close to Kuantu Field and the waterfowl protection area. Considering the surrounding environment, the image of the bridge, and the river channel location, the main bridge, named as Shezi Bridge, was designed as an inclined pylon cable-stayed bridge, with asymmetric span configuration. The shape of the structure adopted the local ecological image of the white egret, indicating a coexisting harmony with the environment. It played a role in integrating regional landscapes. The design concept is shown in Figure 21.
Since the pylon of the Shezi Bridge is 105m tall with a 78 degree inclined angle, it was extremely difficult to set it up. Taking the transportation and lifting capacity into consideration, we decided to divide the whole pylon, from the bottom part linking the bottom beam to the top, into 11 segments. However, if we lifted and welded every single segment one by one, the inclined pylon would need a huge number of temporary supporting frames and welding at high position and will take a longer time and at a higher cost. Deliberating about the lifting ability of the domestic cranes, the available space on the deck, and the efficiency of the construction, we firstly melted four blocks, including No.2 to No.5, into one block on the ground. Then we lifted the whole block with rotation mechanism. The fabrication of the pylon is shown in Figure 22. After that, we used large cranes to lift the rest blocks and set them up in order.

The cantilever construction method was used to lift the main girder for the cross-river part. After the assembling of the components was completed on the deck of the Beitou side, the assembled main girder was
lifted to the floating platform on the river with the 400T overhead moving crane. Then, the segment was transported to the predetermined position, and lifted it onto the certain position simultaneously with two fixed working gantries of the main girder.[4] The photos of the girder construction are shown in Figure 23.

![Fig.23 The main girder construction of Shezi Bridge](image)

5. CONCLUSION

Due to more awareness of the environment and landscape protection in recent years, steel bridge design not only adopts a large span configuration to reduce the number of piers, but also put more attention into its structural shape, by taking advantages of its high strength, light weight and mostly, commonly used material in long span bridges. According to the mass production of steel, the rapid development of the commerce industry society, and the reduction of labour manpower in recent years, steel bridges has become far more widely used to satisfy the requirements of rapid fabrication and labour-saving.

Although steel bridges has many advantages, rapid construction, high strength and light weight. The most serious problem of steel structure is corrosion, especially for bridges exposed outside which makes the maintenance cost higher as well. Therefore, improving the anti-corrosion technique to reduce its maintenance costs would be necessary to clients.

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