Construction of the Nhat Tan Bridge (Vietnam-Japan Friendship Bridge)

Chodai Co., Ltd., Nippon Engineering Consultants Co., Ltd., IHI Infrastructure Systems Co,. Ltd., and Sumitomo Mitsui Construction Co., Ltd.

Introduction

The main bridge of the Nhat Tan Bridge is the largest bridge project to be constructed in Southeast Asia using Japanese ODA (with STEP conditions). The bridge is part of Ring Road No. 2, which connects central Hanoi to Noi Bai International Airport in Vietnam.

In consideration of the river conditions (the river's cross-sectional area blockage ratio) and the optimized construction cost, the bridge was considered as a six-span continuous composite cable-stayed bridge with five pylons. Such a bridge is rarely seen in the world (bridge length: 1,500 mm and central span: 300 m). Chodai Co., Ltd., Nippon Engineering Consultants Co., Ltd and TEDI (Transport Engineering Design Inc., Vietnam) executed the basic design, the detailed design and the construction management. IHI Infrastructure Systems Co., Ltd. and Sumitomo Mitsui Construction Co., Ltd. JV performed the construction work. The bridge was opened in January 2015. Photo 1 shows a general view of the bridge.

Photo 1. General view of the Nhat Tan Bridge

1. Overview of the bridge

Figure 1 is a general drawing of the bridge. The superstructure is a composite girder structure consisting of two steel I-girders and a precast reinforced concrete (RC) deck slab. The main cables are new-PWS cables. The pylons are constructed of A-shaped reinforced concrete. To ensure the construction precision at the cable anchoring points, the steel-cable anchor boxes are mounted on the top of the pylons. The steel-pipe sheet-pile well foundation is Vietnam's first.

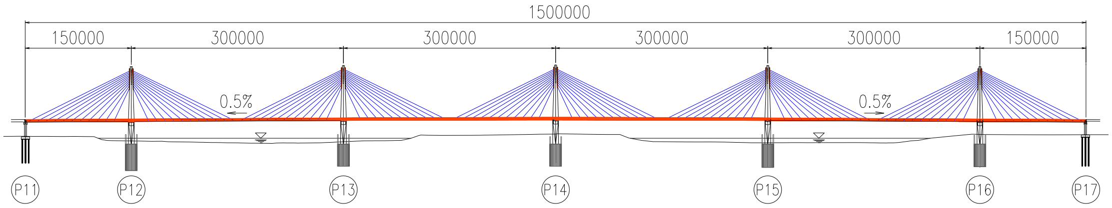


Figure 1. General drawing of the bridge (profile)

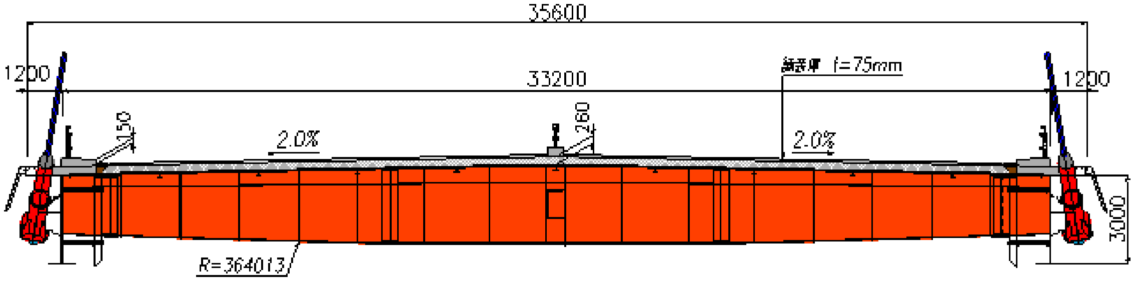


Figure 2. Section of the bridge

Table 1. Overview of the Nhat Tan Bridge

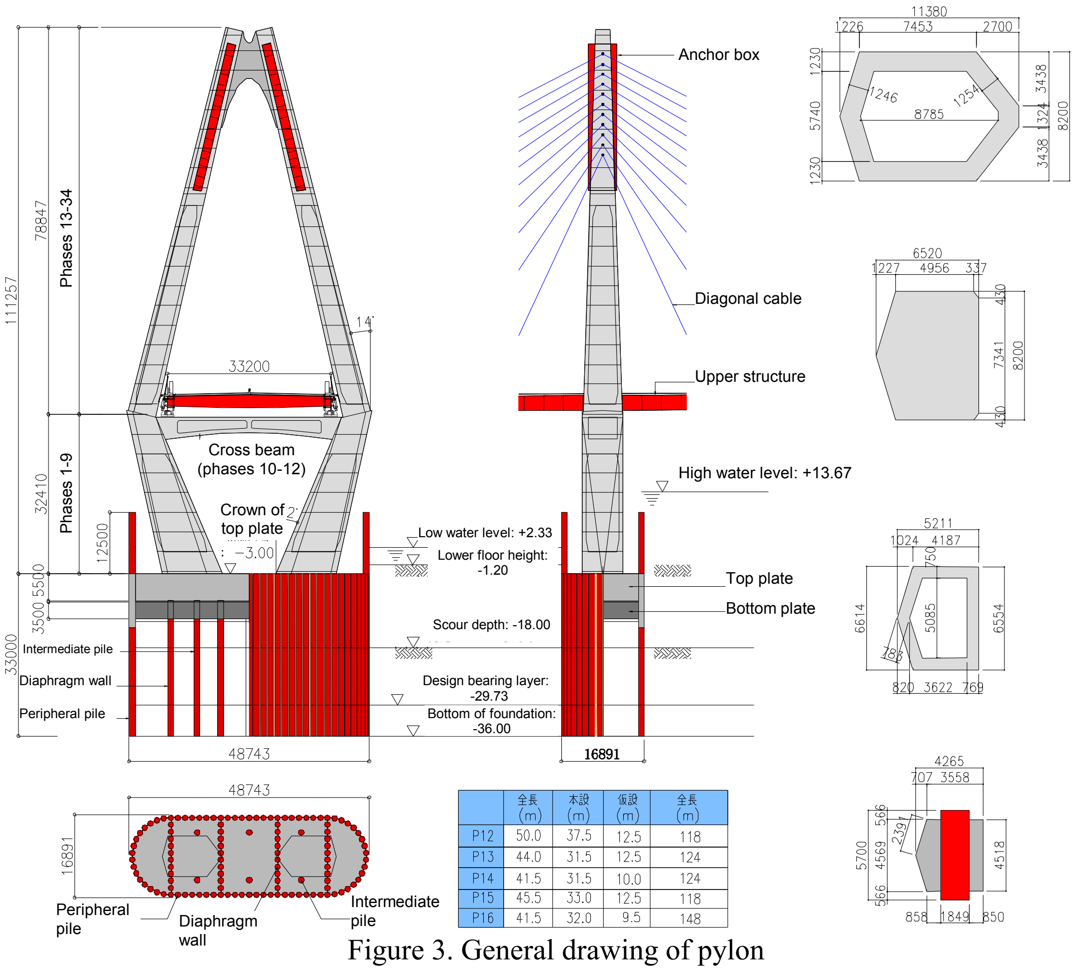
Location of bridge	Hanoi City, The Socialist Republic of Vietnam
Owner	Ministry of Transport PMU85
Work period	October 2009 to December 2014
Main bridge	Two steel I-girders, six-span continuous composite cable-stayed bridge
Quantity of work	<u>Superstructure:</u> Steel weight: 14,500 tf Concrete: 15,900 m^3 Steel reinforcement: 3,129 tf <u>Substructure:</u> Steel-pipe sheet piles: 14,200tf Concrete: 58,000 m^3 Steel reinforcement: 8,900 tf

2. Plan and design

The foundation system consists of a steel-pipe sheet-pile well foundation that can serve also as a temporary cofferdam during work inside the river and ensures high rigidity. This is the first time for such a system to be implemented in large-scale overseas project.

Because the multi-span continuous cable-stayed bridge acts as a flexible structure in the bridge-axial vertical direction, the pylon section was designed to increase the rigidity of the whole structure in order to avoid excessive deformation. Moreover, an A-shaped pylon was adopted to enhance rigidity in the bridge-axial transverse direction. The pylon is reinforced concrete (maximum pylon height: 111 m), with steel anchor boxes embedded near the top of the pylon to anchor stay cables. A model was created and studied to determine how to give highly rigid pylon a slender appearance.

The superstructure is composed of two I-girders (edge girder type: girder height: 3 m) that has a light weight and is economical. The composite girder structure uses a precast RC deck slab (partially prestressed concrete deck slab). Wind tunnel tests were conducted to verify that fairings could help ensure the required level of safety in winds. The stay cables are new-PWS type (tensile strength of wires: 1,770 MPa).



	全長（m）	本設（m）	仮設（m）	全長（m）
P12	50.0	37.5	12.5	118
P13	44.0	31.5	12.5	124
P14	41.5	31.5	10.0	124
P15	45.5	33.0	12.5	118
P16	41.5	32.0	9.5	148

Figure 3. General drawing of pylon

3. Fabrication of steel members

All 14,200 tons of steel pipes used for the steel-pipe sheet-pile well foundation were fabricated based on JIS standards and Japanese-made products.

The following three companies fabricated the steel girders and steel anchor boxes (14,500 tons in total), of which about 83% was fabricated in factories in Vietnam. During fabrication, we worked to transfer Japan's advanced steel bridge technology to Vietnam.

Table 2. Fabricated quantities (by weight) at factories

Factory	Fabricated members	Quantity (tons)
IHI Aichi factory	P14 Main girders, horizontal girders, and vertical girders	2,500
IHI Infrastructure Asia Co., Ltd (Hai Phong, Vietnam)	P13, P15, and P16 Main girders, horizontal girders and vertical girders	7,600
Mitsui Thang Long Steel Construction Co., Ltd. (Hanoi, Vietnam)	P12, Main girders, horizontal girders, and vertical girders Anchor boxes	4,400

4. Construction of steel-pipe sheet-pile well foundation

The steel –pipe sheet-pile well foundation is oval in shape and measures 48.7 m x 16.9 m. The pile is 1.2 m in diameter, the steel plate is 14-22 mm thick, the maximum length, including the temporary structure, is 50 m, the total number of piles, including intermediate piles, is 632, and total weight is approximately 14,200 tons. Alluvial silt and sand sit on the bearing ground, which is a diluvial sand gravel stratum.

To construct the steel-pipe sheet-piles, the positions were determined using temporary rulers. First, hydraulic vibro-hammers combined with a water jet were used to sink the lower piles. The lower piles around the perimeter were then connected together to form a well. Next, the upper piles were welded together at the site. The piles were sunk from pile end to 6D (D = the diameter of steel-pipe sheet pile) and finally driven into the bearing stratum using diesel hammers. Prior to construction of the peripheral piles, single piles were driven to verify the ultimate bearing capacity by means of impact loading testing (PDA). The dimension and vertical accuracy immediately after forming the well were within ±100 mm and 1/500, respectively. The deformation of the steel-pipe sheet-piles after excavating inside of form were within allowable values. Thus, the quality required of a steel-pipe sheet-pile foundation was ensured.

Photo 2. Vibro-method combined with water jet

Photo 3. Final driving using diesel hammers

5. Construction of pylons

With respect to a vertical line, the 111 –m high pylon tilts 22 degrees at the lower leg and 14 degrees at the upper leg, and the section varies three-dimensionally. The steel reinforcement was designed in accordance to AASHTO standards; the main reinforcement bar is D51, and the hoops and intermediate bar are D22-D28. They total 550 kg/m^3 at the hollow section.

Considering the sharp inclination and complex sectional shapes of the pylons and the need for safe operations at great heights, the project employed self-climbing floor integrated with steel formwork. The formwork system ascended and descended by means of hydraulic jacks along an H-type steel rail mounted on special embedded anchors, the formwork system freely changed to accommodate the varied sectional shapes of the pylon.

To enhance the precision of reinforcement assembly and reduce the work period, the reinforcement bars were assembled on the ground (prefabrication) and erected all at once. The shape of the prefabricated cage was retained by means of steel frames with H-type steel arranged vertically. The prefabricated steel cage were assembled in a dedicated yard, transported to a predetermined place, and erected by tower cranes. The capacity of tower cranes limited the total weight of the prefabricated cage to 26 tons.

Photo 4. Installation of self-climbing work floor

Photo 5. Erection of prefabricated steel cage

6. Construction of superstructure

The river plays an important role as a navigation route to the sea, and restrictions on river traffic for long periods of time is not possible. Because of this, steel girder blocks around the pylons were erected on diagonal temporary bents. For the other steel girder blocks, the balancing cantilever erection method using cranes arranged on the bridge deck was employed. In most cases of balancing cantilever erection, the girders in the side spans are first erected by means of temporary bents. In this project, however, the girders for all of the spans, including the side spans were erected using the balancing cantilever method. This was done using 150-t and 50-t cranes arranged on the bridge deck. The main girders involved four closing operations. During the third and fourth closings, because the opposite side of the erected area was restrained, very rigid structures were needed to be connected. This required strict shape management and careful planning and coordination during erection period.

The operations in the bridge-axial vertical direction were coordinated by the setback and forwarding of bearings and the appropriate arrangement of counterweights. The arrangement of various cranes on the bridge deck was also strictly managed. In the bridge-axial transverse direction, special tools capable of coordination to 80 mm were developed for use in this operation.

Photo 6-8 shows the erection process at the site.

Regarding shape management, first, various effected factors were calculated, including the temperatures of structural members, the coordination of shim quantities, and the influence of the equipment load acting on the bridge deck, etc. These calculated factors were then assigned to the control values in all of the erection steps using a proprietary precision erection control program. Thus, the adjustment value of the cable's tensile force at the site was automatically computed.

As a result these tasks, the elevation and the cable's tensile force satisfied the allowable values at all measured points after all the spans were connected, which eliminated the need for adjustment of cable force after closing. Due to all of these efforts, the construction period for the superstructure of the main bridge was shortened by about four months from the contracted work period.

Photo 6. Erection by means of temporary diagonal bent

Photo 7. Erection by means of balancing cantilever erection method

Photo 8. Closing of main girders

7. Pavement and monitoring

The pavement was constructed by applying the highest grade of Polymer Modified Bitumen Asphalt (PMB), Type 3, which has a high softening temperature. This was the first time for the material to be used for bridge in Vietnam for surface and binder courses.

A monitoring system was installed to constantly monitor temperature changes and displacements of the pylons, steel girders, and deck slab, as well as precipitation, wind direction and velocity, cable temperature, tensile forces, etc. The system has been tracking changes in the bridge since it went into service and ensures the accuracy of the bridge design principle.

Photo 9. Construction of pavement

8. Conclusion

The opening ceremony for the bridge was held on January 4, 2015. The ceremony was attended by Mr. Oota, Minister of Land, Infrastructure, Transport and Tourism of Japan, the chairman of the Vietnamese National Assembly, the Vietnamese Minister of Transport, and many other VIPs, as well as local residents. The bridge has reduced the travel time from airport to Hanoi city by about 20 minutes. The bridge has now become a landmark in the region due to its beautiful night-time illumination. We hope that, 100 years into the future, the Vietnamese people will love this bridge as much as they love the historically famous Long Bien Bridge.

Photo 10. Illumination of the bridge