CONSTRUCTION OF THE FIRST STEEL TIED ARCH HIGHWAY BRIDGE AND TREND OF STEEL BRIDGE APPLICATION IN THAILAND

BY

APICHAI WACHIRAPRAKANPONG*
PUTTHIPONG HALEERATTANAWATTANA**
APICHART BURANAKULKITJAKAN***

SYNOPSIS:

The Department of Rural Roads constructed a steel bridge crossing the Nan River in the northern region of Thailand. The construction was completed in December 2021. After that, the bridge became a significant landmark of Phitsanulok City.

The structure is 116 meter long, comprising a steel tied arch bridge for the 80-m long main span across the navigation channel and steel plate girders composite with concrete deck for the approach spans. There are 7-m wide roadway, serving 2 traffic lanes, between the arches and 3-m cantilever sidewalk and bike lane at each side. The bridge is realized as the first steel tied arch bridge for highway in Thailand.

Application of steel in bridge construction tends to increase, because bridges with longer span length are demanding, while accelerated on-site construction period is concerned. Furthermore, owing to its lightweight, replacement of steel superstructure on existing good-condition substructure can be a solution for repair and enhance load-carrying capacities of old bridges.

Keywords: steel bridge construction, steel tied arch bridge, trend of steel application

* Director of the Bureau of Bridge Construction, Department of Rural Roads, Bangkok, Thailand
** Director of Bridge Construction Supervision Group III,

Bureau of Bridge Construction, Department of Rural Roads, Bangkok, Thailand
*** Civil Engineer, Department of Rural Roads, Bangkok, Thailand

Introduction

The Department of Rural Roads (DRR), Thialiand, has responsibility for planning, constructing, and maintaining rural road network that enables people to travel in comfort, with high speed and safety. DRR has also carried out construction of missing links, by-passes, or shortcuts to support urban developing, to promote tourism, and to address traffic problems in community area. Until now, about 45,000 kilometers of roads and 10,000 bridges, throughout the country, are in charge.

In 2015, the Phitsanulok Municipality had requested the department for the design and construction of a new bridge crossing the Nan River in front of the Chan Royal Palace, an ancient palace that was the birthplace of the great King Naresuan, during the Ayutthaya period (A.D. 1350-1767). Now, the palace is the location of the shrine of the great king Naresuan, and also the historical center. On another bank of the river is the famous temple, Wat Phra Si Rattana Mahathat or Wat Yai, in which the golden Buddha statue named Phra Buddha Chinnarat is situated. Every day, plenty of Thai Buddhists and foreign tourists come to visit the temple and pay the homage. As shown in Figure 1., there are other nearby attractive places, such as Wat Nang Phaya, Wat Wihan Thong, city hall, city pillar shrine, etc.

One of the objectives of the bridge is to connect the Chan Royal Palace to Wat Yai. Because of limited parking lots at Wat Yai, tourists can park their cars at the Palace and look around comfortably. It is obvious that the bridge supports the tourism in surrounding area. Consequently, the design of the new bridge shall be unique so that it may be a new attraction and become a new landmark of the city.

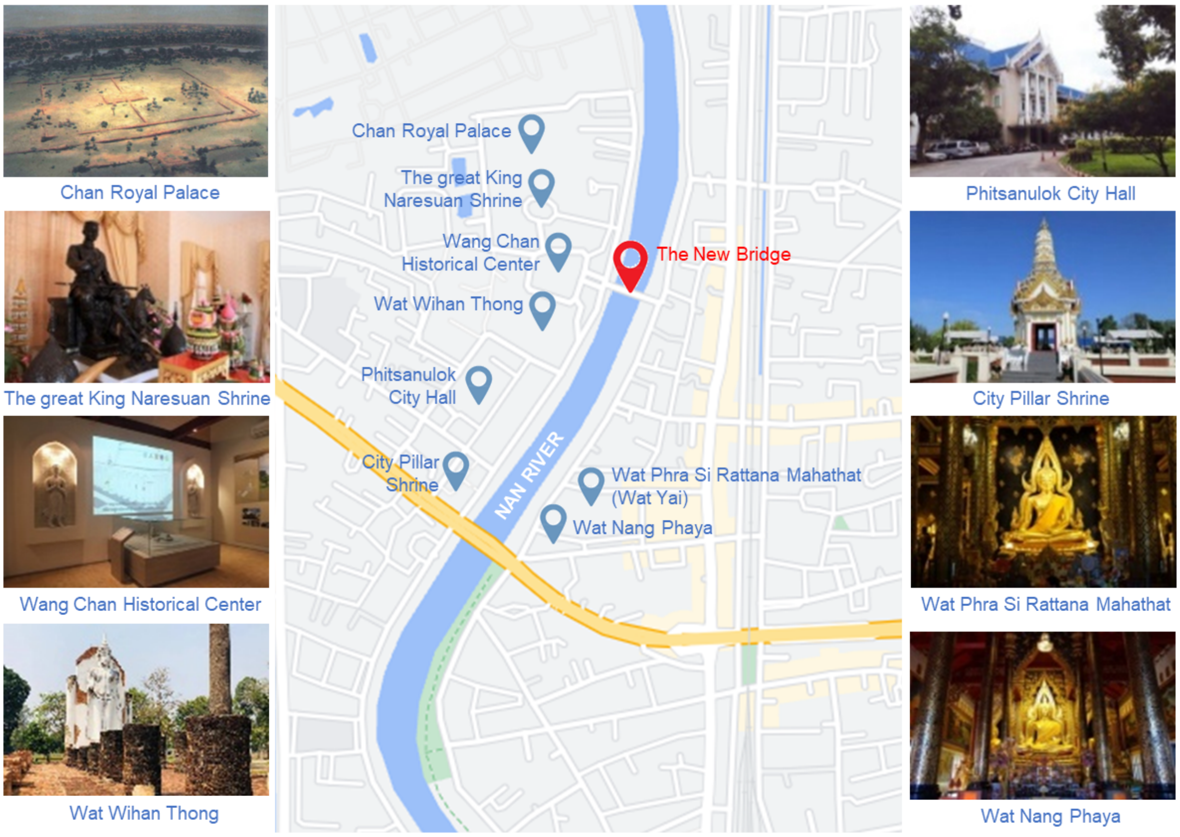


Figure 1 - Location of the new bridge

Bridge Design

Structure and material of the bridge was determined from a few major constraints. The main span across the navigation channel shall be long enough to avoid locating bridge piers in the river and being obstacles to traditional long boat racing along the river. Depth of the superstructure shall keep low, so that the bridge can link two riverbank roads without steep slope of the approaches. Width of the river in vicinity of the bridge is approximately 80 meters. Consequently, truss or tied arch structure was the most suitable. However, truss bridge seemed to be old-fashioned, tied arch structure became the proper solution. Furthermore, due to its lightweight, steel was selected to be main material for the bridge. Figure 2 shows 3D conceptual model of the new bridge.

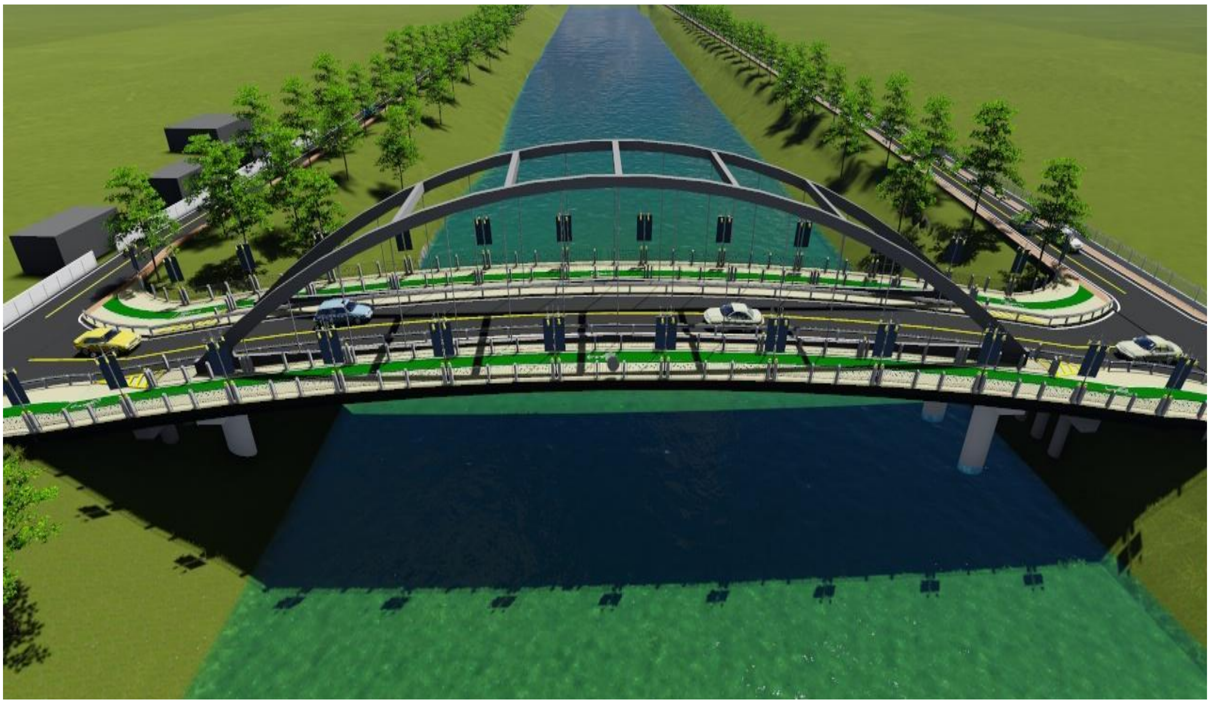
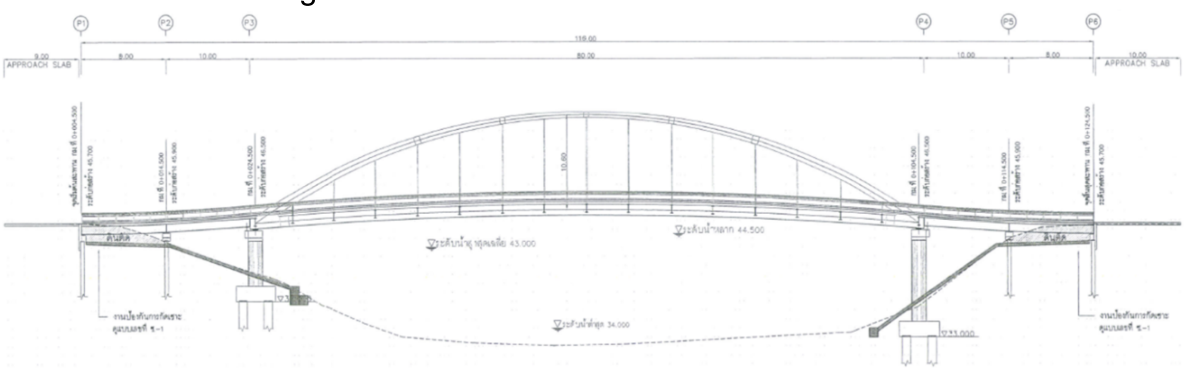


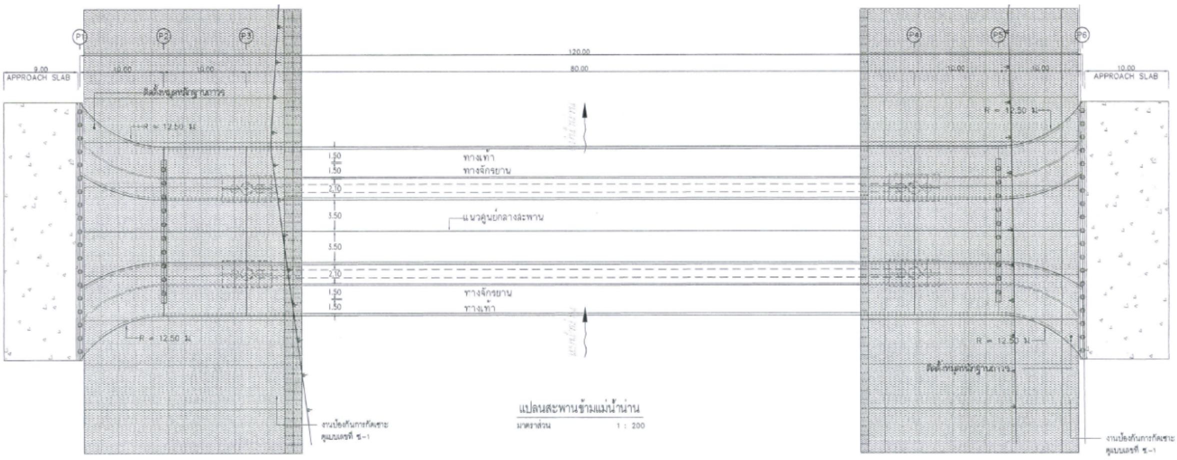
Figure 2 - 3D conceptual model

Figure 3a and 3b show elevation and plan of the bridge. While cross section at pier and at mid-span show in Figure 3c and 3d. Total length of the bridge is 116 meters. The main span is 80-m long steel tied arch bridge. The arches are plate girder box section Rise of the arches is 10.6 meters. There are 13 pairs of M52 hanger rods supporting steel plate girders composite with concrete deck. The approach spans are also composite deck. The bridge serves for 2 traffic lanes. The 7-m wide roadway is between the arches. There is 3-m combination of sidewalk and bike lane, cantilever from both sides of the arches. Because the cantilever length is rather long, additional strut pipes are also applied to support the sidewalk and bike lane.

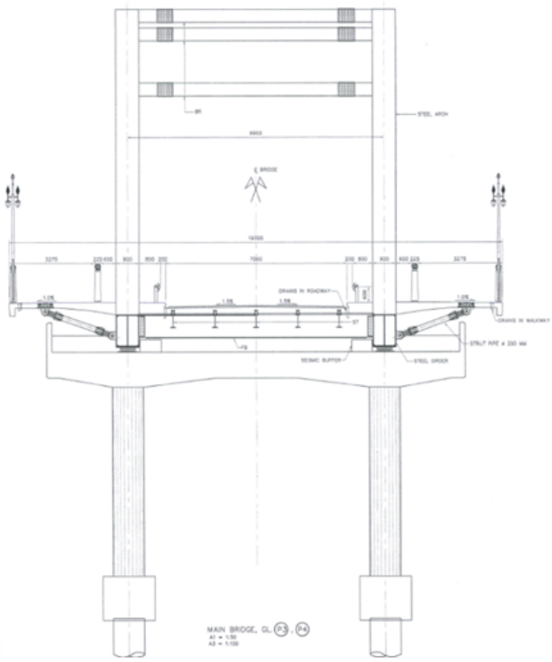
The bridge superstructure lies on pot bearings, which are on reinforced concrete substructure. For the main span, the substructures are double columns, supported each by two of 1.2-m diameter and 35-m long bored piles. While, for the approaches, the substructures are pile bents, supported by a group of bored piles with 0.6-m diameter and 16-m long.

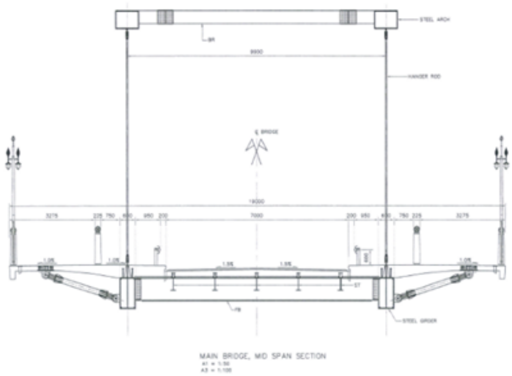


a) Elevation



b) Plan





c) Section at pier   d) Section at mid-span

Figure 3 - Bridge Drawings

Material Used

Conforming to TIS1227-2558 [1], hot rolled structural steel and plates for general use are SM400, with yield tensile strength of 245 MPa. But, in the production of steel arches and girders that higher yield tensile strength is required, steel plate shall be SM520, with yield tensile strength of 355 MPa, conforming to TIS1479-2558 [2]. Steel pipes, used as strut pipes, are also SM520, conforming to TIS107-2561 [3]. Yield and ultimate tensile strength of the hanger rods shall be not less than 870 and 1080 MPa, respectively. ASTM A490 high strength bolts, A593 nuts, and F436 washers are used for on-site bolt connection.

Reinforcing steel is SD40, with yield tensile strength of 395 MPa, conforming to TIS24-2559 [4]. Compressive strength of concrete at 28 days is 25 MPa for piles and bridge deck, and 35 MPa for substructures. Stud connectors for composite deck follow ASTM A108.

Construction Method

West Coast Engineering company limited was awarded for bridge construction with the overall budget of 79.95 million baht. The construction was commenced in September 2019.

After site preparation, the contractor did bored piles. 8-m long steel casing was pressed into the ground. Auger and bucket were used to remove the soil down to the required depth. Below the casing, well-controlled polymer solution was used for hole stabilizing. Drilled hole monitoring was carried out to confirm uniform diameter and inclination of 1:100. Reinforcing steel cage was placed into the hole and concrete was poured with tremie pipe. When the concrete was aged and the pile top was removed, seismic test and sonic logging test were performed to guarantee pile integrity. In addition, dynamic load test was also done to evaluate pile capacity. Safe load is at least 600 ton for piles with diameter of 1.2 m, and 120 ton for ones with diameter of 0.6 m. Consequently, footings, columns, and cross beam were cast in order. Pot bearings would be installed on cross beam next.

During construction of the substructure, fabrication of steel members was carried out in a factory. Before fabrication, deflection of the whole structure under its own weight was calculated. Shop drawings were prepared with the prescribed deflection. Then, steel plates were cut and drilled by machine, and welded together by skilled workers. The fabricated members were pre-assembled to check compatibility of connections, as well as dimension and deflection of the whole structure. When, there was any deviation, the correction would be done. After that, the structure was disassembled. The members were galvanized, and double layer coated with corrosion protection painting.

The well quality-controlled members were delivered and assembled on site. The girders for approach spans were laid readily on piers. But temporary supports were necessary for main span installation. Three towers with access platform were built temporarily in the river. There were two navigation openings with adequate lightings for transportation of small boats.

a) Bored hole drilling b) Construction of footings and columns

c) Construction of crossbeam d) Completion of substructure

Figure 4 - Construction of substructure

a) Cutting b) Welding

c) Pre-assembly d) Checking of dimension

Figure 5 - Fabrication woks

a) Installation of approach span b) Installation of main span

c) Installation of hanger rod d) Stud connectors and deck reinforcement

e) Installation of strut pipes f) Reinforcing steel of footpath

g) Completion of superstructure installation

Figure 6 - Installation of superstructure

After installation of temporary support, lower arches were assembled first. Floor beams were installed next, following by top arches and top bracings. Later, hanger rods were set up with internal tension forces specified in construction drawings. Elongations of hanger rods, deflection of the arches, and longitudinal movement at joints were monitored in every step of installation.

Then, stud connectors were attached on the top of entire floor beams. Precast plank girders were laid as bottom formwork for casting reinforced concrete topping. One end of strut pipes was connected to lower arches by high tension bolts, while the other one was rest on temporary support before casting reinforced concrete cantilever sidewalks.

When installation of the superstructure was completed, architectural items, such as decorating lighting poles, guard rails, and arch tails, were attached as well as safety accessories.

Figure 7 - The bridge when it completed

Figure 8 - The bridge as a part of bike trail

During COVID pandemic, the construction suffered from lack of labor, making the construction delay. But, because the bridge is steel structure, the construction can be accelerated and completed finally. The bridge was opened for the traffic in December 2021. It was a new landmark of Phitsanulok Province.. Now, the bridge has been named “Wang Chan Bridge”, according to the location in front of Chan Royal Palace.

Application of Steel Bridges in Thailand

Steel bridges had been introduced in Thailand by foreign engineers since more than 130 years ago. Many historical bridges in inner Bangkok area were built with steel. But, because of poor durability, they were re-constructed with reinforced concrete.

Nevertheless, some steel truss bridges crossing Chao Phraya River were still in service until present, with periodically repair and maintenance.

Almost all of railway bridges are steel bridge. Most of them are exceeding 80 years old. In recent years, they were big repaired and strengthened to enhance their load-carrying capacity up to U20.

Because, steel cannot be produced in Thailand, it is necessary to import steel from abroad. In addition, Thai contractors are familiar with concrete work. Consequently, since A.D. 1970, most bridges have been built with concrete. However, Rama IX Bridge, the first cable-stayed bridge, was used steel as a main material. Steel has been implemented in the construction of other cable-stayed bridges too, as a part of composite bridge deck.

Figure 9 - Pan Fa Lilat Bridge (Re-built) **Figure 10** - Putthayodfa Bridge

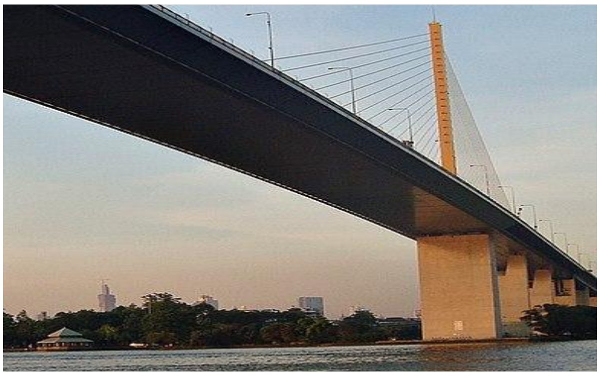


Figure 11 - Railway bridge strengthening **Figure 12** - Rama IX Bridge

It has been appreciated that steel bridge can accelerate construction. Then, steel bridge has been the best choice to be built crossing high traffic volume intersection in Bangkok. In 2022, the construction project of 1.5-kilometer long steel interchange will be started on Rachapruek road, of which the traffic volume exceeding 150,000 cars per day.

Furthermore, with the advantage of light weight, steel bridge becomes popular to build long span bridge with aesthetic. Like Wang Chan Bridge, steel tie arch bridges were constructed as parts of MRT blue line. In near future, there will be another highway tie arch bridge, with main span of 150 meters, crossing Chao Phraya River, in Singburi Province.

With the advance of material science, corrosion drawback of steel can be corrected. The new technology of weathering steel will be applied in the construction of bridges above elephant crossing between Khao Ang Rue Nai Widelife Sancturary and Khao Chamao National Park, in Rayong and Chandraburi Province.

Figure 13 - MRT arch bridge **Figure 14** - Future arch bridge

Conclusion

Wang Chan Bridge was built to be an important landmark of Phitsanulok Province. The main span is 80-m long steel tie arch bridge. Although, the bridge construction suffered from lack of labor during COVID-19 pandemic, the construction was accelerated and completed on time. It is an advanatge of steel material. Moreover, because of beneficial properties of steel and present technology of steel production, there will be steel bridge construction projects taken place continuously in Thailand.

References

[1] Thai Industrial Standard Institute (2015), **Hot Rolled Structural Steel Sections,** TIS1227-2558**.**

[2] Thai Industrial Standard Institute (2015), **Hot Rolled Flat Steel for General Structure**, TIS1479-2558.

[3] Thai Industrial Standard Institute (2018), **Carbon Steel Tubes for General Structure,** TIS107-2561.

[4] Thai Industrial Standard Institute (2016), **Steel Bars for Reinforced Concrete: Deformed Bars,** TIS24-2559.