Extradosed Bridge in Thailand
— Nonthaburi Bridge —

タイ王国初のエクストラドーズド橋
— ノンタブリ橋 —

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Synopsis
Nonthaburi Bridge (**Fig.1**) is 30km north of Bangkok in the province of Nonthaburi in Thailand. Because the crossing of Chao Phraya River has a width over 300 meters, an extradosed bridge with a 200m span was selected for economic and environmental reasons. Although cable stayed bridges have been constructed by oversea contractors in Thailand, no extradosed bridges had yet been built. Nonthaburi Bridge was the first extradosed bridge constructed in Thailand, with Japan's ODA (Official Development Assistance).

Structural Data
Structure: 3-span continuous extradosed bridge
Bridge Length: 460.0m
Span: 130m + 200m + 130m
Width: 32.8m
Tower Height: 27m
Owner: Department of Rural Roads, Thailand
Designer: Epsilon Co., Ltd., Thailand
Contractor: Sumitomo Mitsui Construction Co., Ltd., Japan
Construction Period: May 2012 – Mar 2015
Location: Nonthaburi Province, Thailand

1. Introduction
Nonthaburi Bridge is a 3-span continuous extradosed prestressed concrete (PC) bridge with a 200-m-long main span and a width of 32.8m. It is one of the largest PC bridges to be erected in Southeast Asia by the balanced cantilever method.

Fig.1 Nonthaburi Bridge

2. Design
(1) Wide Section
The bridge is 32.8m wide and supports a six lane road and a walkway. The maximum girder height is 6.8m (**Fig.2**).

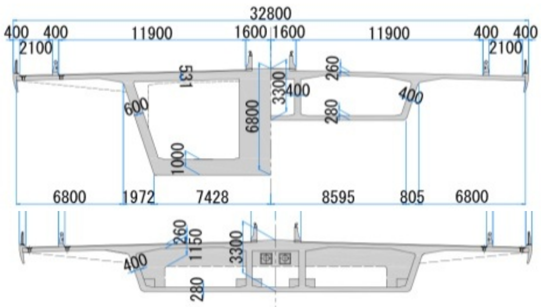

Fig.2 Bridge section

(2) Stay Cable

A stay-cable system runs from 31S15.7 to 55S15.7 (capacity: 15,345kN). On both sides of the bridge deck, in a single plane, 48 stay cables are arranged transversally in parallel and vertically in a fan shape in 12 layers. The stay cables are supported by a novel steel saddle system in the pylon (**Fig.3**).

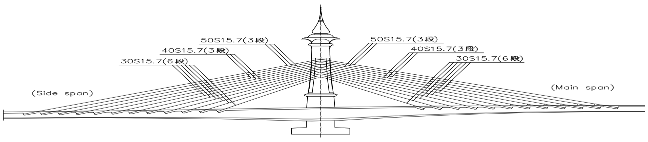

Fig.3 Stay cable arrangement

(3) Fatigue Test

A full-scale fatigue test was conducted at the Vienna University of Technology in Austria as detailed in **Table-1**. Also, a static load test was conducted using the minimum tensile force, which is 95% of the nominal guaranteed ultimate tensile strength (GUTS) of steel (**Figs.4 and 5**).

Table-1 Fatigue test conditions

Anchorage system: DYNA Grip, type DG-P31 (DYWIDAG-Systems International)	
Test specification fib bulletin 30	
Tensile strength (GUTS): 1,770N/mm^2	Deviation of bearing plate: 10 mrad
Cable force 60% of GUTS	Test frequency: 20Hz
Force variation100N/mm^2	Load cycles 2 million

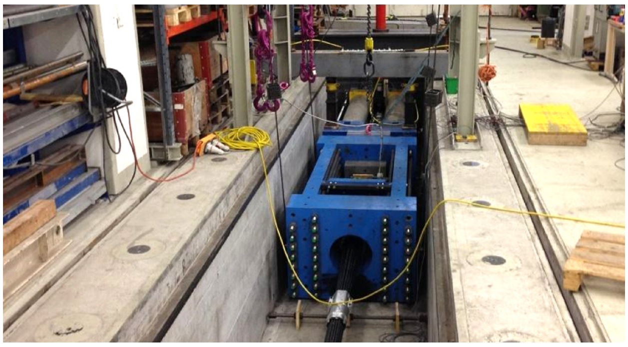

Fig.4 Fatigue test

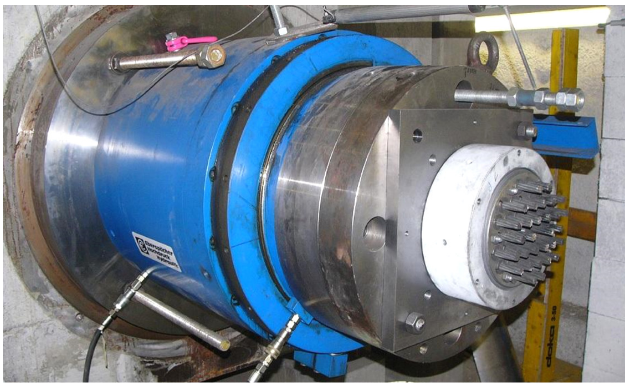

Fig.5 Center hole jack (capacity: 20MN)

(4) Saddle System

The new DYNA Link Anchor Box System was used. This has replaced conventional saddle systems and is based on a steel structure that anchors the stay cables at bearing plates at both ends, as shown in **Fig.6**. One anchorage end comprises the bearing plate and two lateral openings for installing and maintaining the grip. The total force from the stay cables runs through the steel section into the saddle body, which consists of two curved I-beams with shear studs. The saddle is embedded in the tower concrete (**Fig.6**).

The following are the advantages of this saddle system compared with a conventional saddle system:

- no fretting fatigue fractures on the stay cables;
- no inspection is required inside the pylon;
- easy maintenance and inspection of anchorages;
- easy installation and stressing of the stay cables;
- easy to replace a single strand on only one side of the pylon.

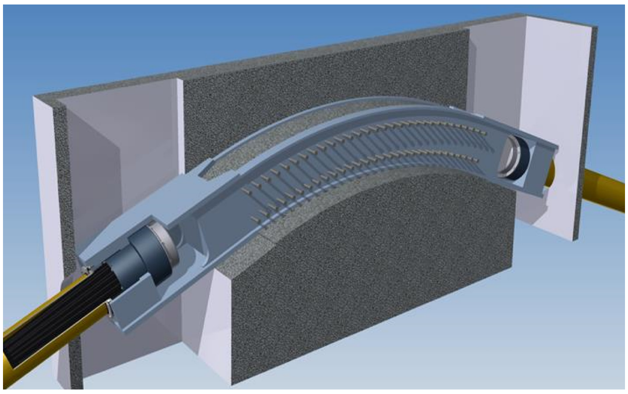

Fig.6 New saddle system

3. Construction

(1) Balanced Cantilever Construction

The method of cast-in-place balanced cantilever erection was used for this bridge. The longest segment was 5m. Transverse rigidity was required because of the single-plane cable-stayed span with a width of 32.8m. Therefore, 1.2m-deep ribs with a spacing of 2.5m were included as part of the design. Because of the 6.8m-long cantilever slab, the ribs were arranged outside the box girder at the same interval of 2.5m (**Fig.7**). To accelerate construction and ensure high quality, these ribs were fabricated as precast elements on the deck and were installed by a form traveler (**Figs.8 and 9**).

(2) Side Span Construction

Precast ribs were used for the side span even though conventional cast-in-place construction was used for the falsework (**Fig.10**).

(3) Stay Cable Construction

The specifications of fib bulletin 3.0 require the directional installation tolerance of the bearing plates and guide pipes to be 5 mrad around the theoretical axis of the stay cable. In addition to coordination control by survey equipment, a laser beam was shone from the pylon side to the anchorage on the deck. This allowed the anchorage to be set in its proper position with high accuracy (**Figs.11 and 12**).

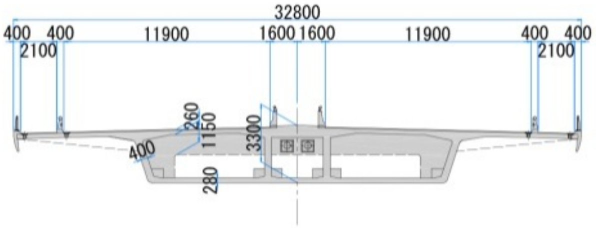

Fig.7 Bridge section (stay cable segment)

Fig.8 Fabrication of precast rib on deck

Fig.9 Erection of precast rib

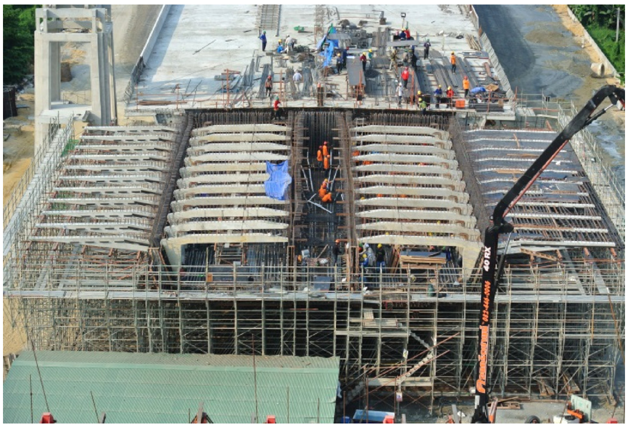

Fig.10 Installation of precast rib at side span

(4) Stay-cable Force Control

To ensure uniformity of force in all the strands in one cable, a mono-strand jack with control system was applied for stressing work (**Fig.13**).

As well as calculating the bridge deformation at each construction stage, the stay-cable force was adjusted to consider the actual deformation during construction. Finally, the tension deviation of one stay cable is a maximum of 1% (allowable tolerance ±2.5%), and the difference in stay-cable force between the design and the actual situation is 3% (tolerance ±5%).

Fig.11 Laser at pylon

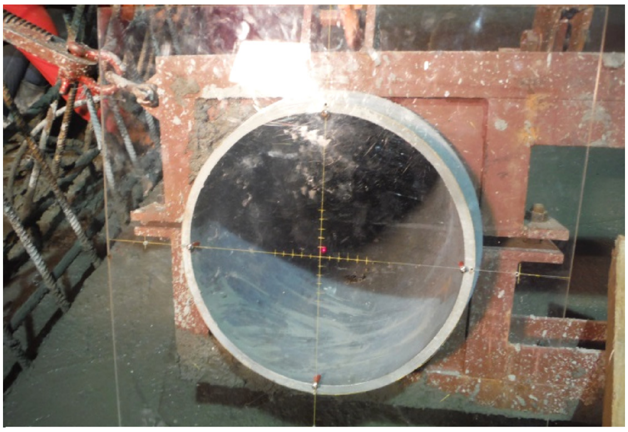

Fig.12 Received laser beam at deck

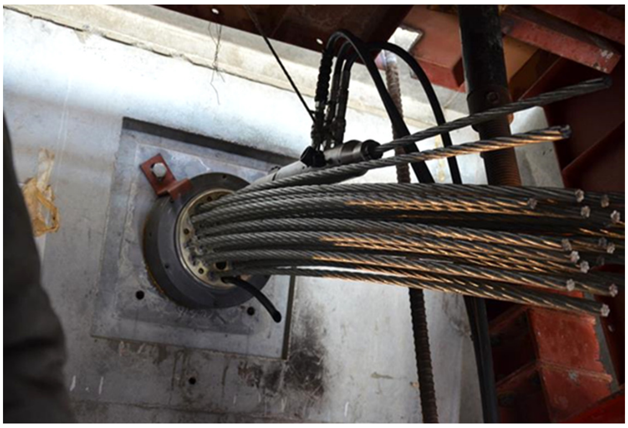

Fig.13 Controlling the stay-cable force

4. Monitoring for Completed Bridge

To monitor the stay-cable force, various sensors of bridge deformation and temperature were installed on the bridge members (**Fig.14**). These can be monitored anytime and from anywhere via the internet. In the event of an emergency related to a stay cable or bridge deformation, the people in charge (client, designer, and contractor) would be informed automatically.

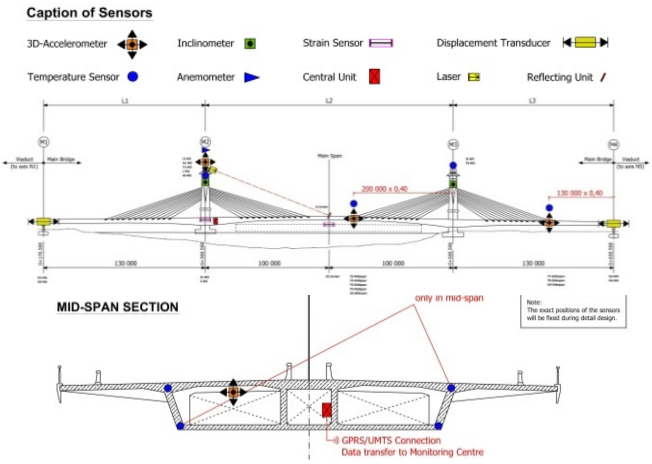

Fig.14 Sensor arrangement

The sensors that measure the stay-cable force are based on the magneto-elastic properties of ferrous material. The stress in a steel element is measured by measuring the corresponding changes in the permeability of the steel. Sensors were installed on 12 of a total of 96 stay cables (**Fig.15**).

Fig.15 Sensor for stay-cable force

5. Conclusion

Nonthaburi Bridge is the first extradosed bridge in Thailand. After project completion, the bridge was named the Maha Jessada Bodin Bridge after the third King of Thailand (the current King is the tenth). 200m main span for crossing the Chao Phraya River, a large 32.8m width, and two pylons, this bridge is the largest extradosed bridge with balanced cantilever method, and so is a major landmark in this area. The features on top of the pylons derive from Buddhism, symbolizing the crown to sit on the lotus. The upper part is of aluminum and the lower part is of fiber-reinforced plastic, reflecting the religion and culture of the Kingdom of Thailand (**Fig.16**).

Fig.16 Overview of completed bridge

References

[1] fib bulletin 30, Acceptance of stay cable system using prestressing, January 2005.

[2] PTI DC45.1-12 Recommendation for Stay Cable Design, Testing and Installation.

[3] Takahashi, T., Saito, N.: Construction of Nonthaburi Bridge, *Bridge and Foundation Engineering*, vol.5, pp. 2-11, 2015. (in Japanese)

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概　要

ノンタブリ橋は，タイ王国初となるエクストラドーズド橋である。

チャオプラヤ川に架かる本橋は，中央支間長200m，幅員32.8mとなり，場所打ち張出し施工工法を適用したエクストラドーズド橋としては東南アジアで最大級の規模となる。広幅員・高桁高となる主桁断面に対し，プレキャスト部材を用いるなどして，品質確保および施工の省力化を図った。

主塔部サドルについては，斜材がサドル内を通過する従来の斜材通過型サドルから設計変更し，斜材がサドル両端部で定着される斜材定着型サドルを適用し，その施工性・健全性を確認した。

また、維持管理の一環として，各種センサーによる橋梁動態観測が今現在も継続的に実施されている。