Sri Lanka: New Bridge Construction Project over the Kelani River — Package 2: Extradosed Bridge Section —

スリランカ ケラニ河新橋建設事業　パッケージ２の施工 ― 広幅員２面吊り形式　エクストラドーズド橋 ―

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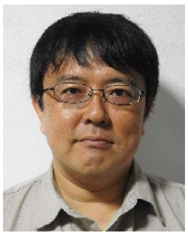 **
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* Shinji SATO: Sumitomo Mitsui Construction Co., Ltd.
佐藤　眞司：三井住友建設（株）
** Masanori SUZUKI: Sumitomo Mitsui Construction Co., Ltd.
鈴木　政則：三井住友建設（株）
*** Takehiko ODATE: Sumitomo Mitsui Construction Co., Ltd.
大館　武彦：三井住友建設（株）
**** Kohei MOMII: Sumitomo Mitsui Construction Co., Ltd.
籾井　仰平：三井住友建設（株）
Contact: shinjisato@smcon.co.jp

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Synopsis
Sri Lanka was colonized by European countries as a maritime trade transit point between east and west Asia, became independent in 1948 as the autonomous British colony of Ceylon, and the country's name was changed to Sri Lanka in 1972. With steady economic growth, traffic congestion has become a problem, especially in the northern part of Colombo, where there is a major traffic hub with four major arterial roads leading to the international airport and Colombo Port. To solve this problem, a new project was funded by Japanese Official Developmental Assistance (**Fig. 1**). This report describes the construction of the first extradosed bridge in Sri Lanka.

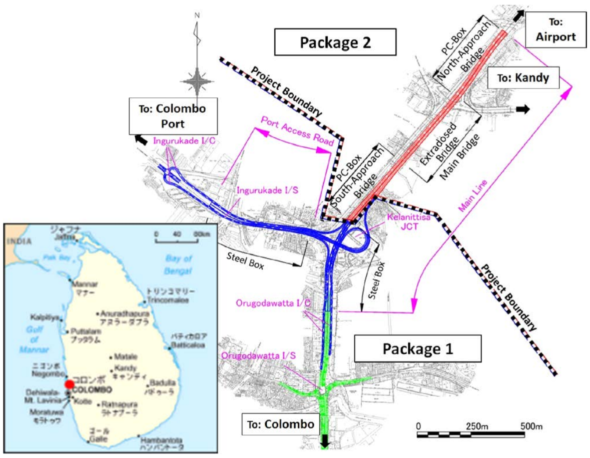

Fig. 1 Location map of project area


Fig. 2 Overview of Kelani extradosed bridge

Structural Data
Owner: Ministry of Highways, Road Development Authority
Designer: Oriental Consultants Global, Katahira & Engineers International Joint Venture
Contractor: Sumitomo Mitsui Construction Co., Ltd. and SANKEN Construction JV
Construction Period: Oct. 2017 - Nov. 2021
Location: North area of Colombo, Sri Lanka

(1) Main Bridge (P19–P22) (**Fig. 2**)
Structure: 3-span continuous prestressed concrete extradosed bridge
Bridge Length: 380 m; *Spans*: 100 m + 180 m + 100 m
Width: 30.4 m; *Pylon Height*: 23.4 m (**Figs. 3,4**)

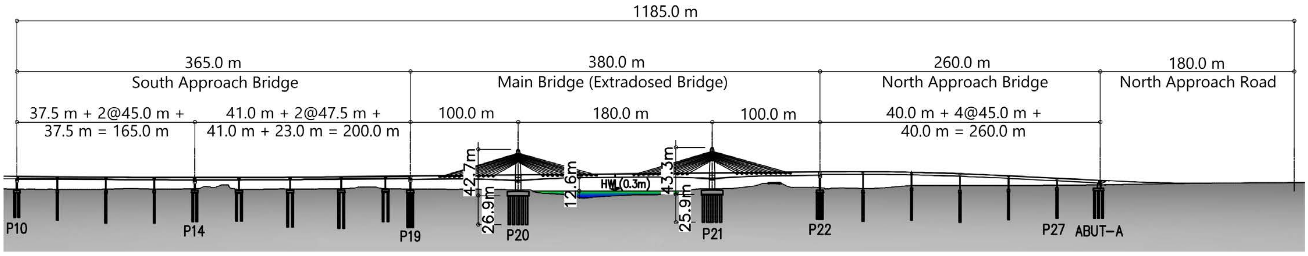

Fig. 3 Overview of the Kelani extradosed bridge

(2) South Approach Bridge (P10–P19)
Structure: 4 and 5-span continuous prestressed concrete box girders
Bridge Length: (165 m + 200 m) × two ways
Spans: 37.5–47.5 m; *Width*: 30 m
(3) North Approach Bridge (P22–Abutment)
Structure: 6-span continuous prestressed concrete box girder
Bridge Length: 260 m × two ways
Spans: 40–45 m; *Width*: 30 m
(4) North Approach Road
Road Length: 180 m; *Height of Embankment*: 0–4.2 m

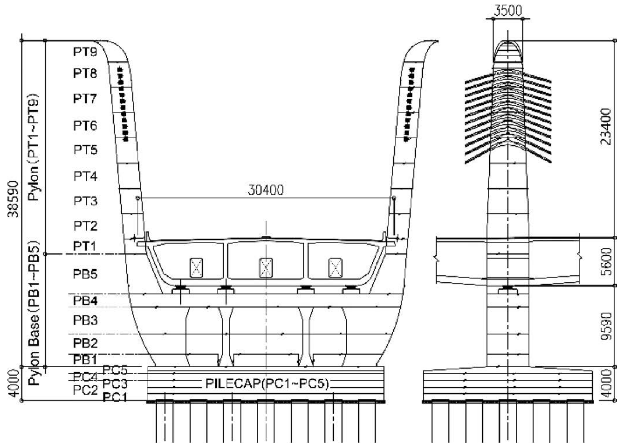

Fig. 4 General view of pylon and pier head (with view of concrete casting layer)

1. Mass Concrete Countermeasures

According to the technical specifications, the maximum internal temperature should be limited to 75°C and the maximum concrete temperature differential should not exceed 20°C during curing. In order to meet these requirements, the following countermeasures were taken when casting the mass concrete members (pile caps, pylon bases, pylons, and cross beams at supports).

1. Using crushed ice in the mix to lower temperature of fresh concrete to below 25°C
2. Using fly ash cement (25% replacement)
3. Conducting an adiabatic temperature rise test on the concrete and thermal stress analysis (FEM) reflecting the test results (**Fig. 5**)
4. Conducting full-scale tests to demonstrate the results of the thermal stress analysis in (3)
5. Conducting heat-retention curing using aluminum vapor deposition sheets to cover the outer surface of formwork
6. Implementing five-layer casting for pile caps (total volume: 2000 m^3) (**Fig. 4**)
7. Implementing pipe cooling (at pylon bases, pylons, and cross beams)

By conducting the above-mentioned countermeasures, quality assured mass concrete members meeting all those requirements were constructed in a convincing way.

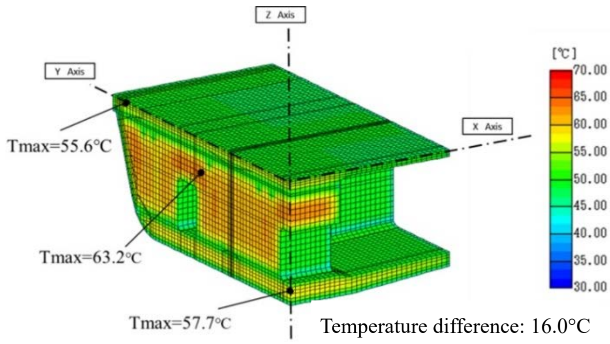

Fig. 5 Maximum temperature distribution of the transverse girder after pipe cooling (1/4 model of pier head)

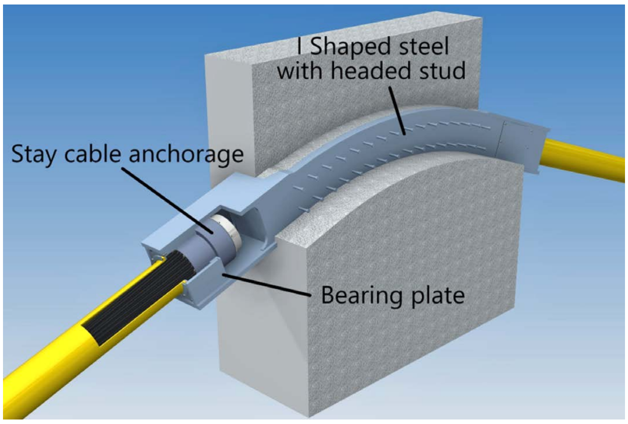

Fig. 6 Stay cable anchorage-type saddle

2. Pylons and Saddles

The pylons were constructed with stay cable anchorage-type saddles (DYNA Link saddles). A bent I-beam with studs was welded to the bearing plates at each end of a box structure, and the anchors are supported by the bearing plates (**Figs. 6,7**). Because the system contains no bent cables, it has high fatigue performance compared with conventional through-type saddles.
The concrete for a pylon was divided into nine lifts ranging from 1.5 to 3.0 m in height.

Fig. 7 Installation of two saddles

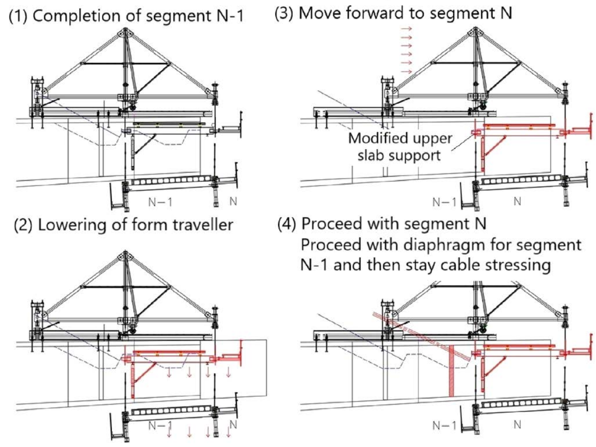

Fig. 9 Sequence of stay cables and diaphragms

3. Superstructure of the Main Bridge

(1) Wide Cross Section

The bridge has a three-box girder cross section with an overall width of 30.4 m and girder heights of 3.3–5.6 m. Three lanes are located on both sides of the median. The stay cables are arranged in a double-plane having 12 cables on each side of pylons outside the parapet walls and are fixed every 4.5 m based on the length of the box girder structural segment. The longitudinal direction is a partially prestressed concrete (PPC) structure reinforced with various prestressing bars and cables (**Fig. 8**).

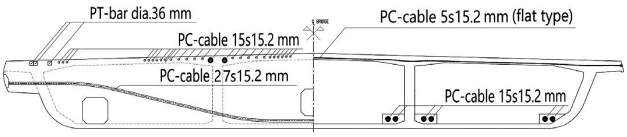

Fig. 8 Arrangement of prestressing steel

Fig. 10 Cantilever construction by form travellers

Fig. 11 3D drawing of form traveller

(2) Pier Head Construction

Specially designed form travellers were utilized not only for the balanced cantilever construction of the girder but also for the pier head construction with help of pile caps supporting those form travellers. The lower formwork system was also designed to fit the shape of the pier heads, and it was lifted up to the girder casting position after the upper trusses were assembled on the completed pier heads. This helped to reduce the construction time and the amount of hazardous heavy-equipment lifting work in the narrow yard.

(3) Balanced Cantilever Construction

The cantilever construction proceeded in 4.0–4.5-m-long segment, with 18 segments on each side. Stay cables are anchored at 4th to 15th segments with diaphragms, and diaphragm construction and tensioning of stay cables were done one segment behind so as not to disturb the critical path of girder construction (**Fig. 9**). The cycle time was 18 days per segment.

A form traveller had four trusses to give it a large capacity of 1,000 tfm (**Fig. 10**). 3D drawings and videos were created to visualize and discuss the assembly and launching mechanism (**Fig. 11**), as well as for educational use.

(4) Stay Cable System

The stay cable system consists of four layers of corrosion protection as follows:

1. Epoxy coated and filled strands (ECF strands), which were made in Japan
2. PE (polyethylene)-sheathing outside of the coated steel strands
3. Wax filled in the gap between the items 1) and 2)
4. Outer sheathing (yellow HDPE (high density polyethylene) tube).

This specification is recommended in the latest European standard (fib Bulletin 89)[1] (**Fig. 12**). The anchorage system is the complete non-grout type and was assembled onsite.

The stay cable strands were erected, tensioned, and anchored one by one, which means that for future maintenance, each strand can be replaced individually if needed. For tensioning of each strand, tensioning force was introduced evenly by using two single-strand jacks at a time (**Fig. 13**).

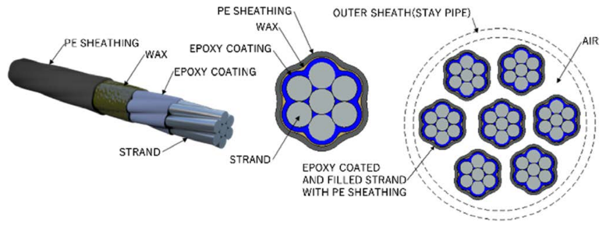

Fig. 12 Four-layer anticorrosion specification

Fig. 13 Tensioning of cable strands

(5) Tension Control of Stay Cables

The stay cables were simultaneously tensioned in the transverse cross section to reduce the torsion of the girders. In the longitudinal right and left directions of pylon, tensioning was conducted from one side to the other side to take advantage of the anchorage type saddle system. It was confirmed in advance that no excessive stress would be generated at the base of a pylon, upon tensioning up to 50% of designed tensioning force at the end side, then up to 100% at the starting side, finally the remaining 50% at the end side. The tensioning was performed during night when main girder displacement due to sunlight did not affect stay cable force.

The tension was managed by tension force using the jack pressure gauge. It was confirmed that the tension error of each strand in the same anchorage was within ±2.5% and that the difference from the design tension was within ±5%, which satisfied the allowable values.

(6) Connecting the Girder

The side spans were constructed in advance using the falsework system and then closed using parts of the form travellers. In the construction of the central closure, temporary H-beams were installed to restrain the displacement in the vertical direction, because the tips of the main girder changed sequentially due to the effects of sunlight.

Also, 72 post tensioning bars with threading (diameter: 32 mm) were installed on both sides of the H-beams and fixed to the main girder to resist displacement in the axial direction by means of their frictional force (**Figs. 14,15**). As a result, the displacement was minimized, and the closure work was completed without cracks or other defects in the concrete at the closure.

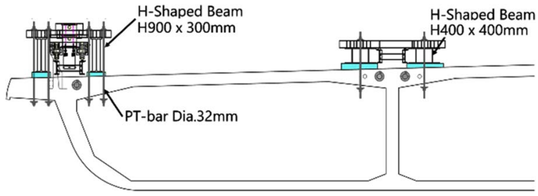

Fig. 14 Displacement restraint of main girder

Fig. 15 Displacement restraint of main girder

4. Conclusion

As the first extradosed bridge in Sri Lanka and the gateway from the airport to the Colombo metropolitan area, this project attracted many visitors and observers. The inauguration ceremony was held in November 2021 and was attended by the President.

Through this project and especially through internships, Japanese engineers trained Sri Lankan engineers, because one of our roles is to train young engineers who can contribute to further economic and national land development in each country. It is hoped that the second and third extradosed bridges will be built by Sri Lankan engineers in the future.

This bridge won the Tanaka Award of the Japan Society of Civil Engineers and an award from the Japan Prestressed Concrete Institute.

Reference

[1] fib Bulletin 89: *Acceptance of cable systems using prestressing steels*, Mar. 2019

概　要

スリランカ : ケラニ河新橋建設事業パッケージ 2 は最大都市コロンボの北部に位置し，上下線各 3 車線から構成された主橋380m，連絡橋625m，連絡道路180m を含む工事延長1185m の橋梁上下部工事である。本稿は，その主橋である PC3径間連続箱桁エクストラドーズド橋の施工について報告するものである。

主橋は中央支間180m，総幅員30.4m の同国最大橋梁かつ初のエクストラドーズド橋である。斜材は PE 被覆 WAX 充填型 ECF ストランドおよび外套管による 4 重防食ケーブルを採用し，将来ストランドごとの交換が可能となる完全ノングラウト式定着体との組合せによる新システムの採用が特筆すべき新技術であり，この施工と併せてマスコンクリートの温度管理対策等を詳述する。