Construction of Steel-Prestressed Concrete Composite Bridge
— Asakegawa Bridge —

鋼・PC 混合 3 径間連続アーチ補剛桁橋の施工
— 朝明川橋 —

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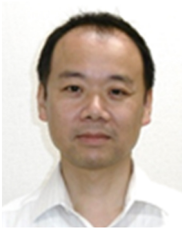 **
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Synopsis
The Asakegawa Bridge in Komaki-cho, Yokkaichi City, Mie Prefecture, is located between the Yokkaichi and Kameyama-nishi junctions on the New Meishin Expressway.
This continuous 3-span bridge measures 325.0m in length, and its longest span is 225.0m long. Additionally, the inbound and outbound lanes form a unified structure with a generous effective width of 23.91m.
The longest span, which is the central span, crosses the Asakegawa River and the National Road No. 365 bypass, and features steel box girders stiffened with arch rib. Both side spans make use of three-cell prestressed concrete, hereinafter referred to as "PC", box girders making this the nation's first composite three-span steel-PC continuous box girders bridge stiffened with arch rib (**Fig.1**).

Fig.1 Asakegawa Bridge

Structural Data
Structure: Composite structure of steel and PC 3-span continuous box girders stiffened by arch rib
Bridge Length: 325.0m
Span: 60m + 225m + 40m
Width: 23.25m
Owner: Central Nippon Expressway Co., Ltd.
Designer: IHI Infrastructure Systems Co., Ltd. Kawada Industries, Inc. Kawada Construction Co., Ltd. Joint Venture
Contractor: IHI Infrastructure Systems Co., Ltd. Kawada Industries, Inc. Kawada Construction Co., Ltd. Joint Venture
Construction Period: Sep. 2011 – Jul. 2016
Location: Mie Prefecture, Japan

1. Introduction
The main girders on the Asakegawa Bridge's PC section feature a wide three-cell box girder cross-section with horizontal ribs attached to the bottom side of the upper slab (**Fig.2**).
In addition, the steel members are attached to the PC members by joining PC steel material to steel plates located behind the joint section (**Fig.3**).

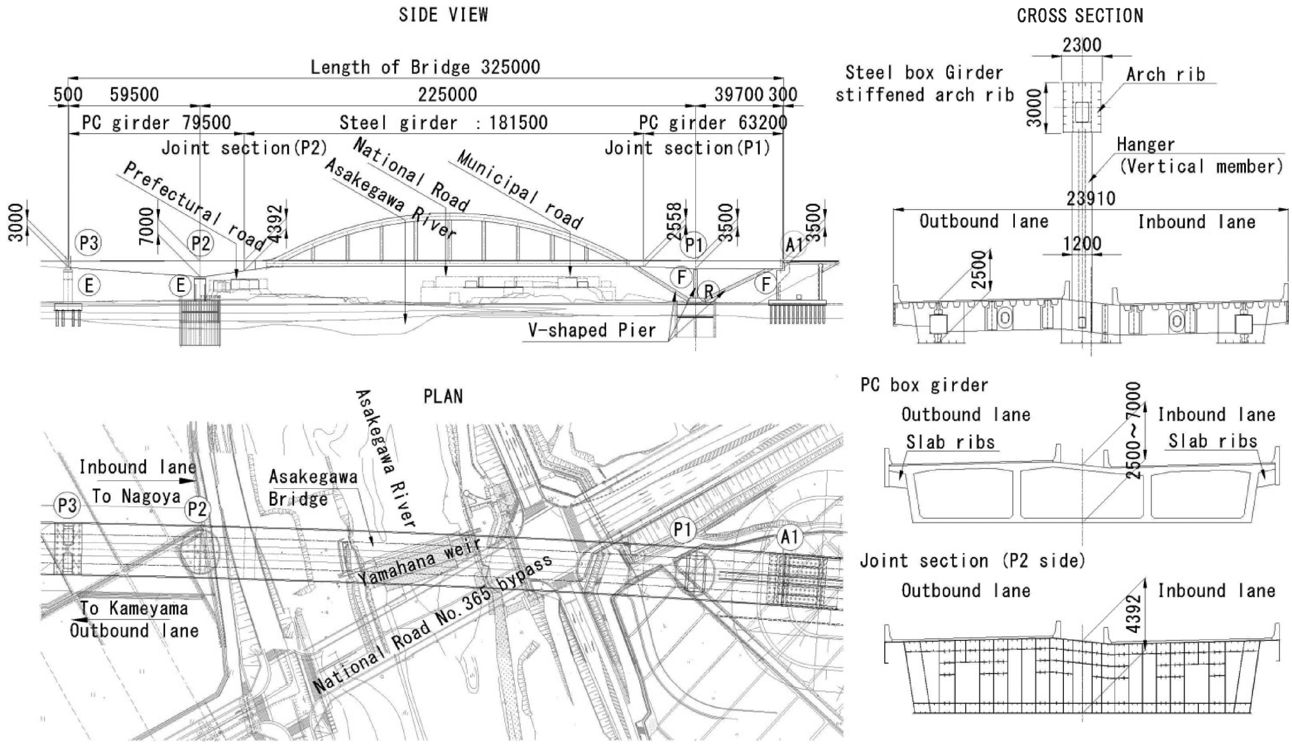

Fig.2 Structural drawing of Asakegawa Bridge

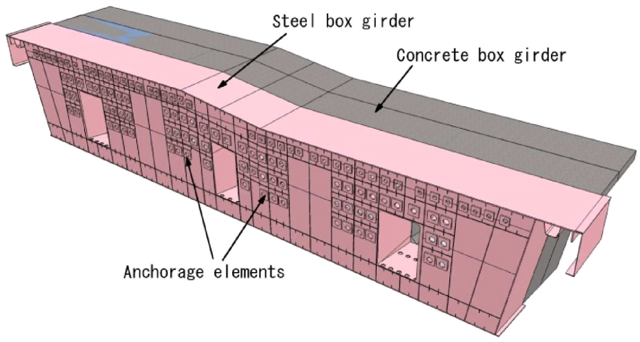

Fig.3 Joint section (P2 side)

Fig.4 V-shaped pier

The side span on the A1 side, which features PC box girders, uses V-shaped reinforced concrete pier with attached vertical member (**Fig.4**). The side span on the P3 side is the starting point for launching erection of the steel box girders stiffened with arch rib (**Fig.5**). The bridge's main structural feature is that its top surface constitutes an assembly yard for these girders (**Fig.6**).
The primary technical challenges faced in construction were "maintaining quality control under unusual construction conditions" and "managing the degree of bridge deflection when attaching heavy steel members".

2. Construction of slab ribs

Because the bridge crosses a roadway, continuous fibers were attached to the surface of the concrete to prevent concrete fragments from falling into the road and causing damage to third parties.
Since the ribs on the protruding upper slab are relatively narrow at a width of 50cm, and because they have a height of greater than 1.0m, the authors expected that there would be difficulties in attaching the continuous fiber sheets to the molds and in assembling the rebar for arrangement on the ribs.
Therefore, the authors created full-scale experimental models and used them to identify problems that might arise during construction, and tried to address any workability issues in advance. As a result, the complex process of placing rebar for the ribs was able to proceed smoothly, and the authors were able to create a high-quality structure (**Fig.7**). [1]

3. Construction of V-shaped pier

The V-shaped pier is reinforced concrete structures rigidly connected to PC box girders. The angle created by the slant members of the V-shaped pier (approximately 30 degrees on the left hand (P2) side, and 25 degrees on the right hand (A1) side) is extremely shallow in comparison with that of more

Fig.5 Launching erection

Fig.6 Assemble arch ribs

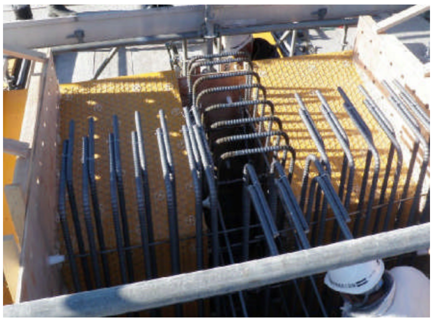

Fig.7 Placing rebar of slab rib

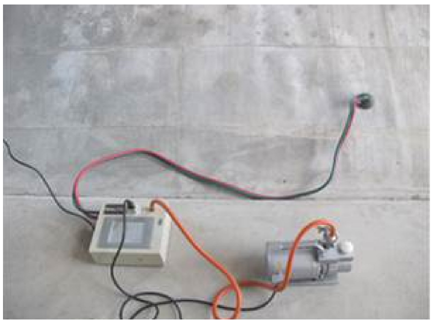

Fig.8 Measure air-permeability

Fig.9 Measure water-permeability

Fig.10 Concrete placement

conventional piers. Moreover, the relatively small 1.5m thickness of the slant members and the large amount of rebar, which includes four layers of D51 rebar as the principle method of internal reinforcement, meant that the construction process would be extremely difficult.

Therefore, prior to the actual construction, the authors conducted full-scale construction tests across several construction scenarios, including a range of situations concerning the molds to be used on the top surface of the slant members, to select an installation method that would produce the highest concrete density and long-term durability.

To evaluate long-term concrete durability, the authors compared two measures of near-surface compactness: the air-permeability and the water-permeability coefficient (**Fig.8**) (**Fig.9**). Based on these test results, the authors decided to install water-permeable molds while pouring the concrete to create a highly durable structure (**Fig.10**). [2] [3]

4. Construction of joint section

The steel and PC girders were joined by attaching PC steel members to steel plates located behind the joint section. Because of the substantial width and the large number of internal and external PC tendons joining together the unprecedented number of steel-shell cells, the authors needed to find a way of reliably filling the members with concrete. The authors determined the best construction method by using the actual pump truck that would be used during construction to select the right blend of high-performance (self-compacting) concrete, and by evaluating the concrete filling performance using full-scale test models (**Fig.11**).[4]

5. Deflection control

The bridge was constructed by installing the PC girders between both side spans and then carrying out basic assembly of the steel girders stiffened with arch rib atop the P3 span to extend them to the A1 side. When they are being joined to the steel arch girders, the PC girders are subject to significant loading due to the weight of the steel arch girders. The authors needed to assess the influence of this loading, especially on the P3 span, which is not firmly supported by the V-shaped pier.

The joint section of the PC girders for the P3 span is located at 20 m on the side of the center span, and crosses a prefectural road. Although the authors had originally planned to support the joint section using a construction bent, the ground strength of the location where the authors had intended to place the bent proved insufficient. Instead, the authors pre-tensioned the PC tendons before installing the joint section so that the PC girders would support themselves without requiring any bents (**Fig.12**).

Also, because the steel arch girders cause substantial vertical displacement of the protruding section, the authors managed the deflection at each construction step.

6. Initial crack control

In addition to the large width of the upper slabs, the construction of the PC girders used a cast-in-place method. As a result, the authors had to pay attention to any cracking of the concrete due to shrinkage prior to the tensioning of the PC tendons. The authors implemented measures to suppress this initial cracking to preserve the durability of the concrete.

Fig.11 Concrete filling test model

Fig.12 PC girder (P3 side)

One such measure was the placement of specialized high-absorption curing mats on the top surface of the upper slabs until the concrete had aged 28 days, and, after removing the molds, the painting of the concrete surface with a high-performance shrinkage suppression material to inhibit initial crack formation. In addition, the authors used thermal stress analysis to confirm that the crack index was greater than or equal to 1.45.
Furthermore, since the cross girders were composed of mass concrete members, the authors examined different cement varieties via thermal stress analysis, and settled

Fig.13 Air pipe cooling

on moderate heat Portland cement. Finally, as further insurance against initial crack formation, the authors implemented air-pipe cooling through the external tendon ducts, installed temperature- and humidity-controlled concrete-curing shelters, and lengthened curing times to achieve a crack index of greater than or equal to 1.45 (**Fig.13**).

References

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概　要

朝明川橋は，三重県四日市市に位置する新東名高速道路の橋梁である。朝明川および国道365号バイパスなどを横過する最大支間となる中央径間には鋼アーチ補剛箱桁を配置し，両側の側径間をPC3室箱桁で連続させた鋼・PC 混合 3 径間連続アーチ補剛鋼床版箱桁橋であり，わが国で初めて採用された構造形式の鋼・PC 混合橋である。

本橋の構造上の特徴として，広幅員断面となる鋼と PC との接合部に後面支圧板方式の接合構造を採用，および，起点側側径間が RC 鉛直材付きの緩傾斜を有する V 脚構造となっていることなどが挙げられる。

その他，広幅員のリブ付き上床版や上げ越し管理などの施工に関する対応，温度応力による初期ひび割れ対策など多くの厳しい技術的な課題があったが，施工技術を駆使することにより，無事工事を完了することができた。