Prestressed-concrete Composite Truss Bridge Harmonized with a Valley
— Hakkou Bridge —

渓谷に溶け込む PC 複合トラス橋
— 白虹橋 —

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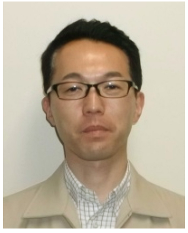 **
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Synopsis
As part of the project to redevelop the Amagase Dam, the Hakkou Bridge was constructed in Uji City, Kyoto Prefecture, as a prestressed concrete (PC) simple composite truss bridge that crosses a valley while preserving its scenic beauty. Because the bridge was to be built in a restricted construction site without hampering the road traffic in the neighborhood or disturbing the natural landscape, a special bridging method known as hanging-slab construction was employed. Because the concept of the bridge regarding the natural landscape was "harmonization with the valley, rainbows, and streams," the bridge was designed to merge into the beautiful natural setting, emphasizing the depth of the valley in the background. The bridge was completed in October 2016 and put into service in March 2017 (**Fig.1**). This paper summarizes how the bridge was constructed, it being one of the first of its type, and the measurements of the bridge taken during construction.

Fig.1 Hakkou Bridge

Structural Data
Structure: PC simple composite truss bridge
Bridge Length: 75.688m
Span: 72.888m
Width: 9.230 – 22.801m
Owner: Ministry of Land, Infrastructure, Transport and Tourism
Designer: Oriental Consultants Co., Ltd.
Contractor: P.S. Mitsubishi Construction Co., Ltd.
Construction Period: Jul. 2014 – Oct. 2016
Location: Kyoto Prefecture, Japan

1. Introduction
The Hakkou Bridge is a PC simple composite truss bridge located at the foot of the Amagase Dam in Uji City, Kyoto Prefecture. It crosses the Uji River, a "Class A" river. A hanging-slab method was used to construct this bridge given the limited site space, the need to maintain the current road traffic, and the advantages in workability and landscape preservation. This construction procedure is a structural concept that takes advantage of the technology of hanging-slab bridges in building the bridge body on cables stretched between the abutments, allowing safe construction

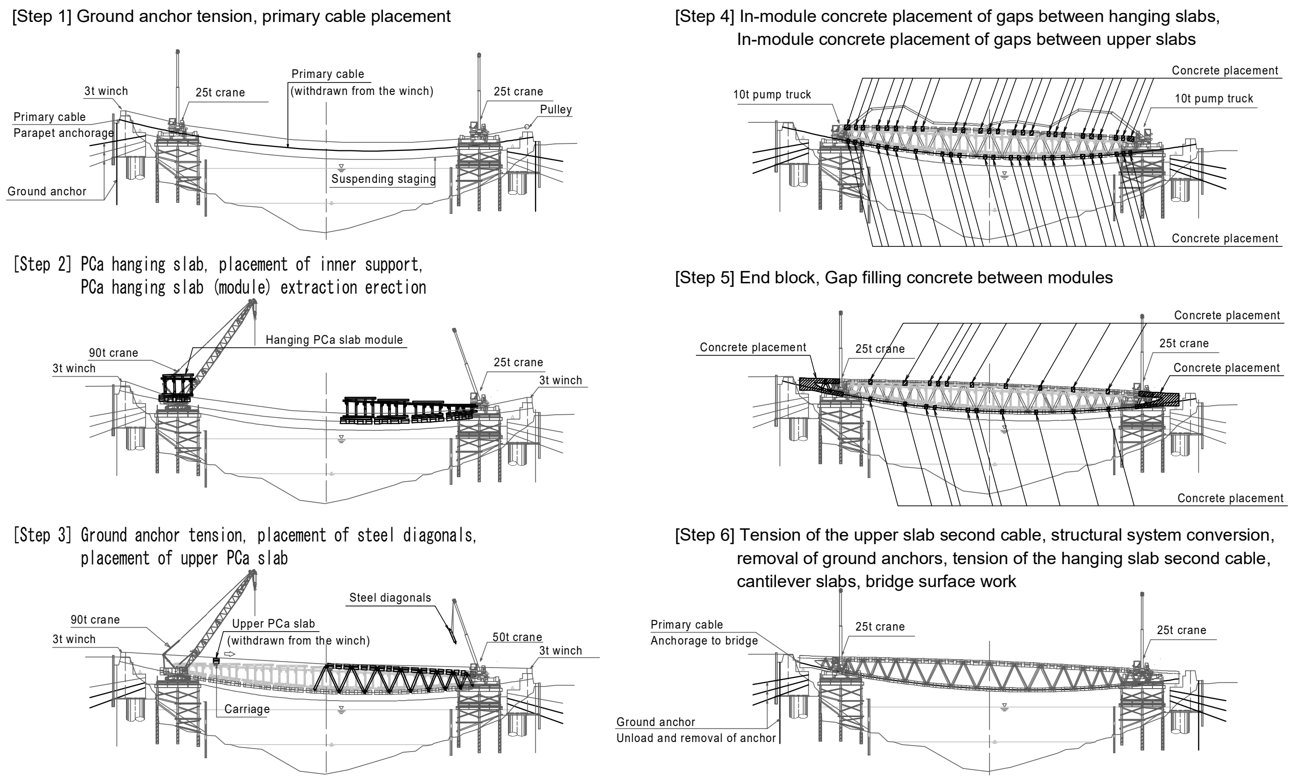


Fig.2 Construction steps

by providing a balance between the tensile force of the cable anchored temporally to the parapet and the force acting at the ground anchor of the vertical wall of the abutment parapet. After completing the bridge body, the cable that was set temporally on the parapet was removed and anchored again to the extremity of the bridge. The bridge system was converted from a hanging-slab structure, relying on other structures, to a composite truss structure with automatic anchoring. This structural model is a new type of structure developed in 1990, but there are only a few bridges of this type in Japan. This bridge has a span length of 72.8m, slightly shorter than the bridges already constructed. It features a small sag for the given span length and involves the new step of assembling precast component modules to form the bridge structure.

2. Construction Overview

The construction steps of the Hakkou Bridge are shown in **Fig.2**. A hanging-slab method was used to construct the bridge, whereby inner supports were placed on the precast (PCa) hanging slab, which was erected on the primary cables, prior to placing steel diagonals and PCa upper slabs (see steps 1–3). Using this construction method, given that the sag increases as the load on the primary cables increases as construction progresses, the bridge geometry had to be managed using a sophisticated technique and steel diagonals and PCa slabs had to be erected.

To cope with these difficulties, a working platform was erected in front of the A1 abutment on the basic assembly stand. The PCa hanging slab and inner support members (four or five pieces for each) were assembled on this platform into a module, and such modules were put in place in a predetermined order. Serving as an on-site work yard, this arrangement made it possible to assemble PCa slabs with higher precision compared with conventional procedures that first assemble all PCa slab plates on the primary cables and then add the inner support members.

(1) Erection of Precast Hanging Slab Modules (Step 2)

Of the prefabricated PCa hanging slabs carried to the site, several (four or five) were transferred to the basic assembly stand, adjusted via inner supports (considering their relative position when completed), and assembled into a module. The PCa hanging slab and the inner support members were adjusted in height with non-shrinking mortar and merged into a monolithic structure with high-strength bolts (**Fig.3**).

The inner support members were planned to keep the geometry of the bridge body as assembled. The slab modules were arranged precisely on the basic assembly stand so that, after erecting the PCa hanging-slab module, the steel diagonals and upper PCa slabs could be placed more precisely.

Meanwhile, the PCa hanging slab as a module was made to be borne entirely on the primary cables by lowering the height of the basic assembly stand with a jack. Then, at the spaces to be filled later, reinforcing bars and forms as gap-filling members were assembled in the PCa hanging slab of a module, and the PCa hanging slab was drawn out by a winch and placed at a predetermined place (**Fig.4**). By assembling in advance, it was possible to reduce intervention points after erection, thereby saving labor and improving erection accuracy and safety.

(2) Placement of Steel Diagonals and Erection of Upper Precast Slab (Step 3)

A crane was used to assemble the steel diagonals directly from working platforms A1 and A2. The intervals and heights of these diagonals were adjusted as required to achieve completed status so that they could be positioned correctly with other components. They were fixed to the inner support members with special band jigs. To erect the upper PCa slab, a drawing-out track and special carriage were installed on the inner support. After the PCa hanging slab and steel diagonals were completed, the upper PC slab was then suspended and transferred to and fixed on the carriage by means of the crane on the A1 side of the working platform. An electric winch was then used to pull out that slab to the A2 side before finally being installed (**Fig.5**). After being extracted to the predetermined position and confirmed in its position relative to the hanging slab, the upper PCa slab was integrated with the inner support members.

3. Measurement of Stresses at Structural Conversion of the Bridging System

Because this bridge was constructed using a relatively unprecedented erection method, the strain acting on the bridge was measured to confirm the safety at the time of erection. The strains on components at the time of a structural conversion, which were obtained by measurement, are discussed below.

The most distinguishing characteristic of this bridge project was a structural conversion wherein the tensile force of the primary cable supporting the slabs and steel diagonals as a hanging system was used to prestress a simple truss girder bridge.

In this structural shifting, the primary cable anchored to the back of the abutment was released and re-anchored to the extremity of the girder. Because this step was crucial in controlling the integrity of the bridge structure, the stress acting on the bridge itself was measured to confirm construction quality.

As shown in **Fig.6**, the stress was measured at 1/2, 1/4, and 1/8 of the span. This was done using an embedded strain gauge and a surface strain gauge. **Fig.7** shows the measured stress levels of the slab and the axial force of the steel diagonals.

The concrete stress of the upper slab was slightly higher than the design value for the span. It is assumed that this was because the prestress introduced into the upper slab was higher in percentage than the design value and the tensile force of the primary cable was marginally larger than the design value. Nevertheless, the measured stress values had a sufficient safety margin compared with the allowable compression stress. Moreover, it was confirmed that the values were negligible, taking into account the increased stress level under the bridge surface load and live loads.

Although the concrete stresses of the hanging slab differed somewhat at point 1/8 L at the extremity of the bridge guider, they were nevertheless approximately equal to the design value. These differences from the design value at point 1/8L are considered to be due

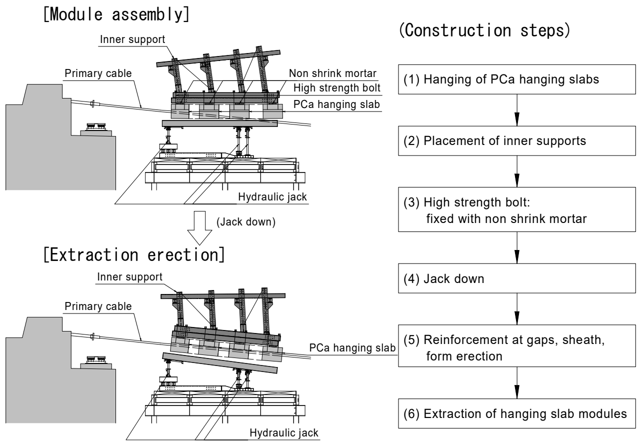


Fig.3 Erection of integrated component of PCa hanging slab

Fig.4 Erection of PCa hanging slab by extraction

Fig.5 Draw erection of upper PCa slab

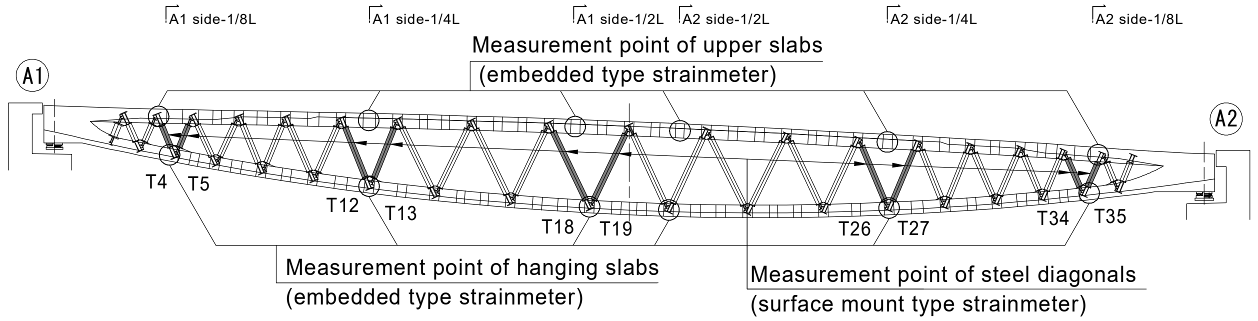
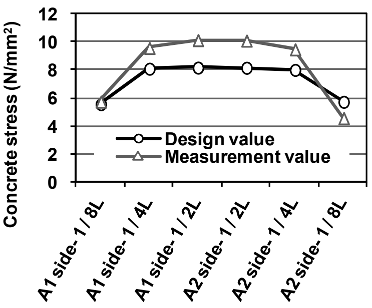
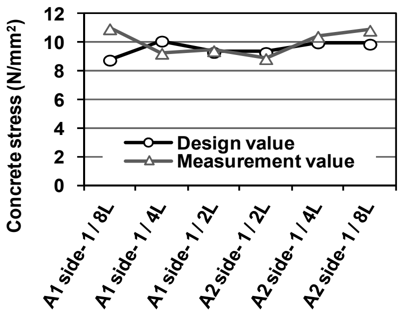


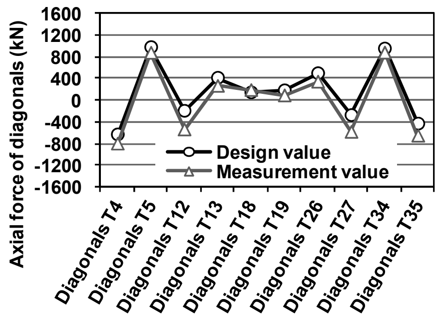
Fig.6 Strain measurement locations slab



(1) Concrete stress of upper slab



(2) Concrete stress of hanging slab



(3) Axial force of steel diagonal

Fig.7 Results of strain measurements

to changes in the section resulting from the curved surface of the bridge extremity. The axial force of the steel diagonal changed in approximately the same way on both the compressive side and the tensile side. The observations above confirm that the behavior of each member, as induced by structural conversion, coincides approximately with the design assumptions.

4. Conclusion

This paper introduces the construction method of a PC simple composite truss bridge that was constructed by the relatively unprecedented hanging-slab construction method. This method, featuring a module comprising a PCa hanging slab and inner support members, demonstrated remarkable performance for saving labor and improving safety at the time of construction.

The authors hope that as time passes, the Hakkou Bridge will blend into the valley setting of Uji River, which has flourishing natural beauty and promotes the region’s vitalization in combination with dam sightseeing.

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概　要

白虹橋は，天ケ瀬ダム再開発事業の一環として，京都府宇治市の風光明媚な景観が残る渓谷に建設されたPC単純複合トラス橋である。狭隘な施工ヤードで，現道交通の確保や既存の自然景観の保全なども求められたため，施工性ならびに景観性の観点から吊床版架設工法が採用された。本橋の景観コンセプトは「渓谷との調和，虹と清流」であり，渓谷の奥行き感を活かして地形の中にすっきりと納まった橋梁デザインとなっている。本橋は，平成28年10月に完成し，３月より供用を開始している。本稿は，架設事例の少ない本工法の施工概要，架設時に実施した実橋計測について報告する。