

Self-anchored Composite Truss Bridge Using a Suspension Structure — Hirono Bridge —

吊床版架設工法を用いた自碇式複合トラス橋 — 広野大橋 —



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Synopsis

The town of Kyotamba is located in the Yura River system of the Tamba mountains in the middle of Kyoto Prefecture. The Omisu River, a tributary of the Yura River in a deep valley, is crossed right under the Hirono Bridge, a single span highway bridge with a span of 107.5 m. This bridge is a self-anchored composite truss bridge, erected using a suspension structure as a temporary form. After constructing the abutments, suspension cables are stretched between them to carry all the subsequent construction load. Lower chord members and steel diagonal members, which are all precast segments, are then placed. After that, the upper chord deck is constructed. After concreting cast-in-place slabs, wet joints and closure pour, the suspension

cables beneath the lower chord are released from the abutments and anchored to the girder. The self-anchoring produces a simple composite truss structure for the completed bridge (Fig.1,2).

Structural Data

Structure: 1-span composite truss bridge

Bridge Length: 111.0m

Span: 107.5m

Width: 8.2m

Owner: Kyoto Prefecture

Designer: Japan Bridge & Structure Institute, Inc.

Contractor: Sumitomo Mitsui Construction Co., Ltd.

Construction Period: Nov. 2009 – Mar. 2011

Location: Kyoto Prefecture, Japan

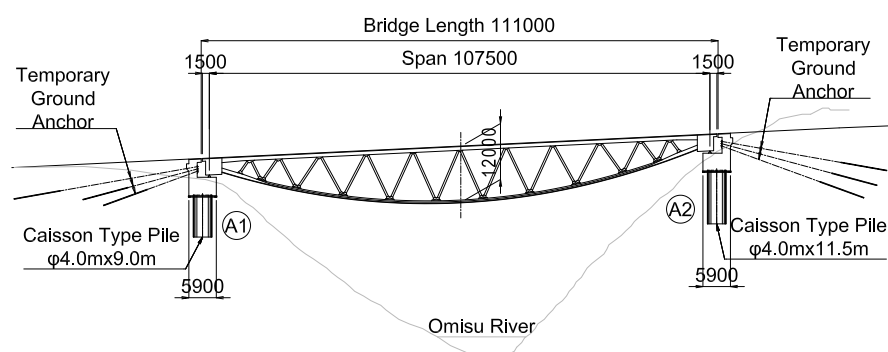


Fig.1 General View

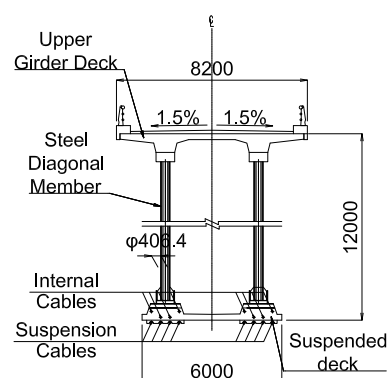


Fig.2 Cross Section



Fig.3 Hirono Bridge

1. Introduction

The Hirono Bridge is a single-span composite truss bridge using precast concrete segments for the deck and lower chord, together with 406.4 mm steel pipes as diagonal members, erected using a suspension structure. The completed bridge is shown in **Fig.3**.

The structure used for this bridge was chosen from a number of suggested structural types, taking account of the natural scenery at the site and of the precipitous topography on both sides of the Omisu River. The structure eventually selected was the best option in terms of economy, ease of construction, and construction period, and in addition, it required the least modification of the terrain. The rationality of these

concrete tension ties is also noted by Marti^[1].

2. Design

In design, analysis took full account of the construction stage for the main part of the bridge. When the structure is supported by suspension cables, finite deformation analysis was used to investigate the structural system during erection. And infinitesimal deformation analysis was used to investigate the eventual structural system of the completed bridge. In addition, the design process included analysis of creep behavior for the composite structure, fatigue design for the steel diagonal members and suspension cables, and verification of torsional flutter to confirm the safety of the bridge during and after construction. Seismic design considerations resulted in a base-isolated bridge design capable of reducing response in a large scale earthquake, using time history response analysis to confirm safety.

3. Construction

The construction procedure is shown in **Fig.4**. The construction method for this bridge involved erecting steel diagonal members and upper deck utilizing falsework assembled on a suspended deck—a stressed ribbon that eventually became the lower chord of the completed bridge. This approach requires no staging or falsework under the bridge, and enables the construction period to be shortened. However, great care and extremely sophisticated execution work are necessary because the shape of the stress-ribbon that determines the form of the falsework changes under the additional load each time a member is added.

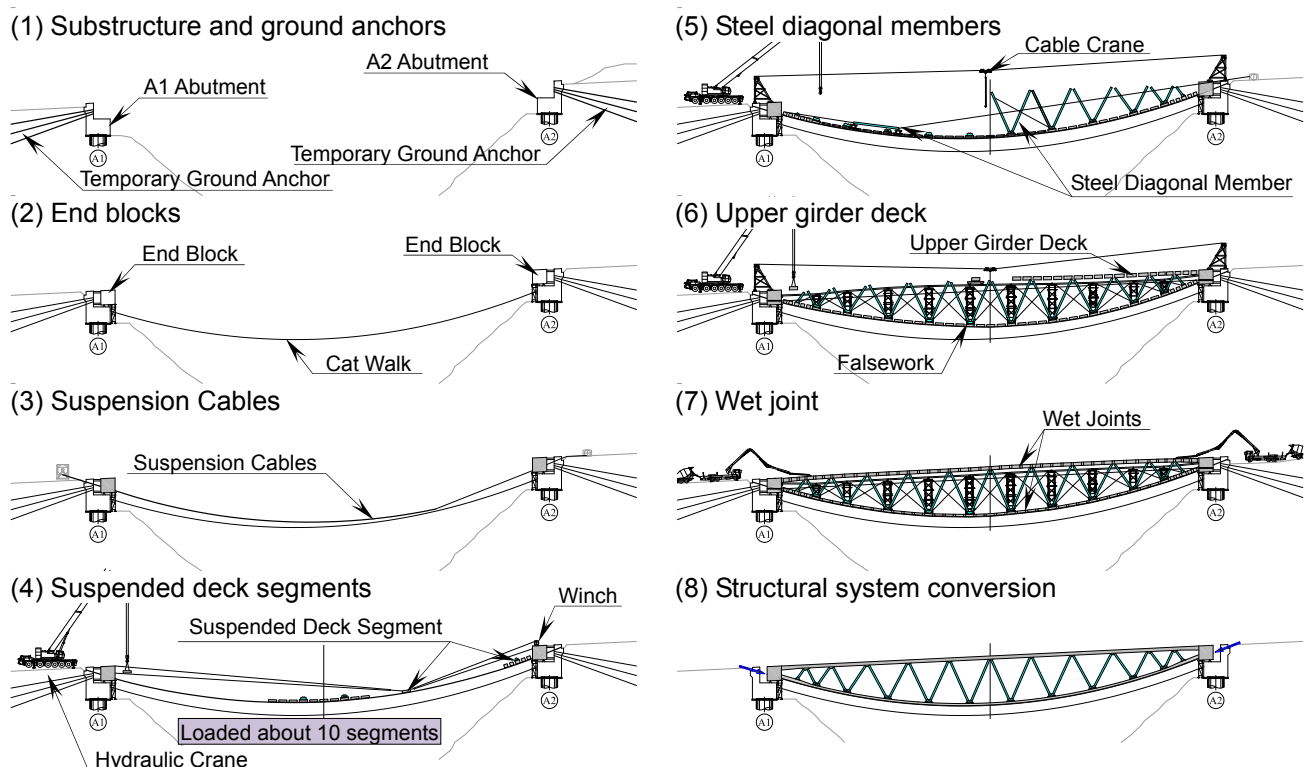


Fig.4 Construction Procedure

(1) Substructure and ground anchors

The ground anchors used for this bridge are temporary structures that are no longer required after the bridge is completed by transformation into a self-anchored structure. However, they play a vital role in supporting the suspension cables during construction, and are essential for ensuring stability during erection of the bridge. Accordingly, particular attention was paid to ground anchor quality and safety, conducting over four times the usual level of verification tests after erection of these structures.

(2) End blocks

The end blocks incorporate bearings as well as the cable anchorages for the completed bridge. Structurally, the end blocks are separated from the substructure on completion, but they need to be fixed in place during erection, so prestressing steel bars and concrete were used to temporarily secure them to the abutments. A cat walk was put in place after constructing the end blocks.

(3) Suspension cables

For the suspension cables, we used threaded anchorage polyethylene sheathed cables like those used for the stays in cable-stayed bridges. With this construction method, the accuracy of primary cable erection has a substantial influence on the overall accuracy of the completed structural system. Accordingly, we attached

gauges at the center of the span and used them to carefully to adjust sag and flatness (Fig.5).

(4) Suspended Deck segments

The suspended deck segments were placed onto the suspension cables using a hydraulic crane, then slid along the suspension cables to their erection positions. In the early stages of this process, the cables had very little geometric stiffness, and a small change in load had a large effect on cable geometry, making the construction work particularly difficult. For this reason, we first loaded about 10 segments onto the cables in the central area of the span, enhancing the overall geometric stiffness of the cables, and facilitating erection of the segments (Fig.6).

(5) Steel diagonal members

The steel diagonal members were erected using a crane and cable crane (Fig.7). After positioning the members, wires were attached to prevent them from toppling, ensuring stability during construction.

(6) Upper girder deck

The upper girder deck segments were erected using falsework installed on the suspended deck, and utilizing trolleys and counterweights. Erection of the upper girder deck segments raised the whole structure's center of gravity, which is detrimental to horizontal stability.



Fig.5 Suspension cables



Fig.7 Erection of steel diagonal members

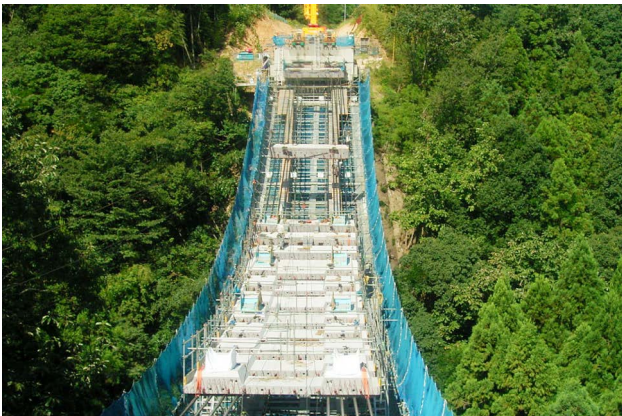


Fig.6 Erection of suspended deck segments



Fig.8 Erection of the upper girder deck



Fig.9 Concrete compaction by revibrating

As a countermeasure, we stretched cables to left and right of the bridge cross-section to enhance the stability of the structure (Fig.8).

(7) Wet joint

Care is required when placing filling concrete in or on the suspended structure, because the additional load causes the shape of the whole structure to change as the concrete is poured. For this bridge, we placed the filling concrete in three separate steps, and began from locations that were least affected by deformation. For the final step, we applied vibrators once more after concrete placement was completed (Fig.9). This enabled the concrete to fill minute gaps that had been produced by overall deformation.

(8) Structural system conversion

At this stage, all segments had been interconnected by concrete, producing a structure capable of being self-supporting. Here, the tension in the suspension cables that had supported the self-weight of the bridge was shifted to the bridge itself, transforming the structure that was externally anchored during construction



Fig.10 Structural system conversion

into a self-anchored structure (Fig.10). With this transformation, horizontal forces no longer act on the abutments, and the tension in the suspension cables acts as prestressing for the superstructure, resulting in a very rational structure.

4. Conclusion

Using a suspension structure for erection of this bridge enabled erection independent of the conditions under the span, and did not require an extensive construction yard. These characteristics make this construction method particularly appropriate for sites with steep or precipitous topography. The post-construction transformation from an externally-anchored to a self-anchored structure results in excellent reliability and seismic performance. The design also requires very little modification to the natural surroundings, making it very effective from an environmental perspective.

References

- [1] Peter Marti: Bridge Girders with Prestressed Concrete Tension Ties, The 1st fib Congress, October 2002

概要

広野大橋は、京都府北中部の綾部市と京丹波町の市町境付近に位置し、一級河川由良川の支川である大簾川を渡河する単純PC複合トラス橋である。本橋は、急峻で深い谷間を跨ぐこと、早期完成を望まれる京都縦貫自動車道(丹波綾部道路)の工事前進入路として使用されることなどから、工事費の縮減と工期短縮が求められた。そこで、谷部に橋脚や仮設材を設ける必要がなく、施工期間の大幅な短縮が可能な吊床版構造を利用した架設工法によるPC複合トラス構造が採用された。

本構造は、橋体架設時において、橋台背面に設置したグラウンドアンカーで死荷重反力に抵抗させ、橋台間に張り渡したケーブル上でトラスの構造体を組み立てるものである。そして橋体構築後、ケーブル張力を橋体端部に移行し、橋体にプレストレスを導入する構造系変換を行い、他碛構造から自碛構造に変換し、安定した単純トラス橋とする特徴を有している。