Design and Construction of a Long Bridge over a Shinkansen Depot — Yaga Overpass Bridge —

新幹線車両基地に架かる長大橋 — 矢賀こ線橋 —

 *
 **
 ***
 ****

* Makoto KAWABATA, P.E.Jp: TAISEI CORPORATION
川端　誠，技術士（建設部門）：大成建設（株）
** Keisuke HANI: West Japan Railway Company
半井　恵介：西日本旅客鉄道（株）
*** Natsumi SAIKI, P.E.Jp: JR West Japan Consultants Company
佐伯　奈都美，技術士（建設部門）：ジェイアール西日本コンサルタンツ（株）
**** Yoichi BABA: KOSEI CORPORATION
馬場　洋一：広成建設（株）
Contact: kawabata@ce.taisei.co.jp
Keywords: fiber-reinforced concrete, mass concrete, operating rail line
DOI: 10.11474/JPCI.NR.2022.129

Synopsis

The Yaga Overpass Bridge is part of Hiroshima Expressway Route 5 and is a temporarily two-lane bridge built by the cantilever construction method. This bridge crosses over a rail depot capable of housing Shinkansen trains with 20 cars. The main span length of 152 m is one of the longest for a continuous concrete web box girder bridge in Japan (**Figs. 1–3**).
In the very limited construction area near the depot, a foundation capable of accommodating future widening to four lanes was constructed, and the superstructure was designed to allow for long-term maintenance and management in the space above the depot.
The Yaga Overpass Bridge harmonizes with the Shinkansen trains and 200 m rows of cherry trees on the north side of the depot, creating a new landscape that will take root in the community.

Fig. 1 Yaga Overpass Bridge

Fig. 2 Panoramic view of depot (before construction)

Structural Data

Structure: 3-span continuous PC box girder bridge
Bridge Length: 321.854 m
Span: 83.100 m + 152.000 m + 83.954 m
Width: 10.0 m (14.0 m including emergency lane)
Operating Entity: The City of Hiroshima
Ordered by: West Japan Railway Company
Designer: JR West Japan Consultants Company
Contractor: Taisei–Kosei joint venture
Construction Period: Nov. 2016 – Mar. 2020
Location: Hiroshima Prefecture, Japan

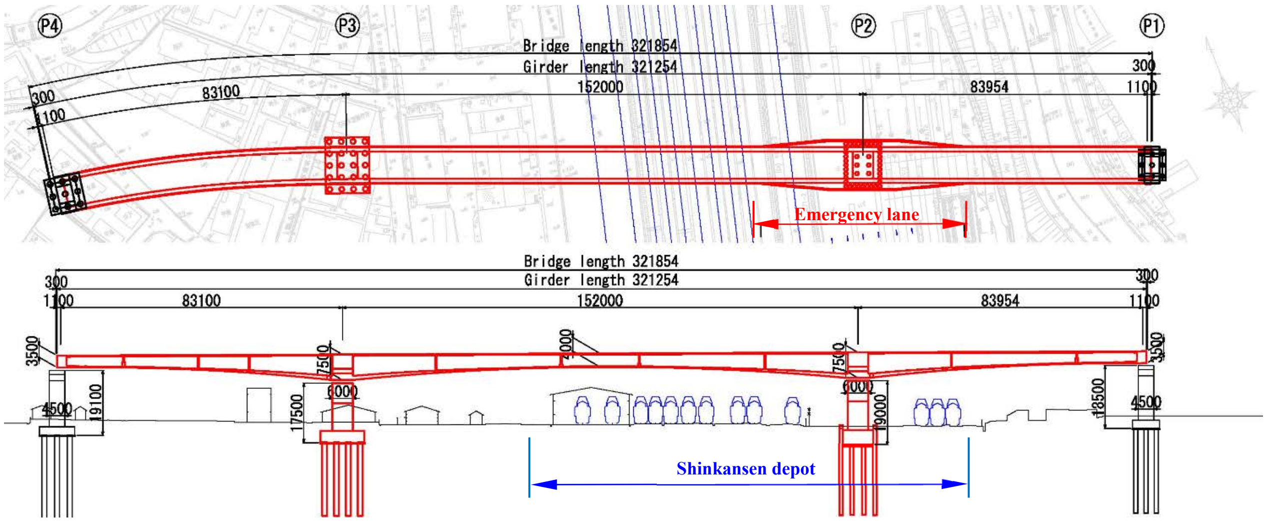

Fig. 3 Overview of Yaga Overpass Bridge

1. Introduction

The Yaga Overpass Bridge is a 322 m, 3-span continuous prestressed concrete (PC) box girder bridge that crosses over Shinkansen depot in an urban area. One of the bridge piers was constructed within a narrow site between tracks of the depot (**Fig. 4**). Since maintenance-related activities cannot be easily carried out from inside the depot once the bridge is opened, the maintenance and quality assurance of concrete and grout were thoughtfully planned and designed. It was also necessary to take measures during construction to prevent interference with the operations of the Shinkansen, which is important lifeline infrastructure.

2. Design

(1) Selection of Span Length and Foundation

To reduce the number of piers, thereby minimizing the construction and maintenance impact on the depot, pier positions were set around 150 m apart, the maximum span possible for the cantilever construction method. Since the location where the pier could be constructed in the depot was limited to the area between railway tracks, the foundation type was chosen to be a steel pipe sheet pile foundation, rather than a large conventional case-in-place pile foundation, allowing it to accommodate future road widening construction.

(2) Improved Substructure Safety

To improve substructure safety, high-damping laminated rubber bearings were installed to disperse horizontal forces during earthquakes while also reducing the response acceleration of the superstructure (**Fig. 5**). In this bridge, designing bearings that accommodate time-dependent shortening of the superstructure such as creep and shrinkage would result in an uneconomic design due to the large shear deformation involved. Therefore, post-sliding was implemented to alleviate deformation of the rubber bearings after construction and to reduce costs. Since use of high-damping laminated rubber bearings increases horizontal movement during earthquakes, modular telescopic devices that allow for movement in all directions while maintaining excellent water-tightness and a level, smooth-riding surface were used for the expansion joints at both ends of the bridge.

(3) A Safe and Fast Solution for Emergency Lane Removal

The existing emergency lane at the P2 pier will be removed during the future road widening. The non-abutment pretensioning prestressing (NAPP) method, which uses pretensioned hollow PC steel bars, was applied to introduce prestressing in the top slab of the emergency lane that will be removed upon conversion

Fig. 4 Bridge pier in train yard

Fig. 5 On-site assembly of rubber bearings

to four lanes. This method compresses concrete members by placing pretensioned hollow PC steel bars at positions in the formwork and releasing that tension after the concrete is placed and cured.

It was assumed that the emergency lane would be removed by cutting with a wire saw, but with general PC steel bars, there was concern that a steel bar might pop out when cut because of deterioration of the grout between the sheath and the steel bar. However, the NAPP method integrates the concrete and pretensioned members, ensuring safety of the removal work during conversion to four lanes.

(4) Improved Maintainability

The Shinkansen trains in the depot are powered by 25,000 V overhead power lines; therefore, a safety distance of 3 m from those lines had to be secured to allow safe use of bridge inspection vehicles under the girders. In addition, short polypropylene fibers were mixed into the upper structure concrete above the depot to ensure long-term anti-spalling performance and to reduce the amount of maintenance work that would be required under the girders.

The superstructure utilizes an external cable system to facilitate inspection and replacement of in-service PC cables by placing some of the PC cables inside the box girder. The external cables are bundled PC steel wires coated with unbonded grease and covered with high-density polyethylene, and entire bundled cables are further coated with high-density polyethylene to provide multi-layered protection for rustproofing, thereby improving durability.

3. Construction

(1) Ensuring Concrete Quality

This bridge, which has one of the longest main span lengths for this type of structure in Japan, required horizontal pipe lengths of up to 76 m for concrete pumping. Since fiber-reinforced concrete was adopted for the superstructure crossing over the depot to achieve long-term anti-spalling performance, loss of workability of the concrete discharged from the long pumping pipe was a major concern (**Fig. 6**). Full-scale testing was therefore conducted to determine how the concrete consistency would be affected by pumping the concrete with the longest pipe expected to be used at the site. The decrease in slump was 2.5 cm due to short fiber mixing, and was 1.5 cm for the maximum pumping length. Also adding decreases in slump of 1.0 cm due to waiting in a ready-mix truck for 1 h at an outside temperature of 32–34 °C and of 2.5 cm due to variations in concrete production, the total expected decrease in slump was 7.5 cm. Thus, the required slump at the end of the pipe was set as 10 cm, and that at unloading was set as 18 cm.

Fig. 6 In-progress construction at maximum cantilever length

Thermal cracking in the mass concrete of the pierhead due to cement hydration was a major concern. A thermal stress analysis was performed, and the concrete mix was redesigned such that crack widths would not exceed 0.2 mm. The top slab was ordinary concrete with an expander additive, and low-heat Portland cement was used for the bottom slab, webs, and pier diaphragm.

During concrete placement, a cloud system was utilized to allow persons in charge at the ready-mixed concrete plant, receiving site, and placement site to access and use real-time monitoring of the concrete delivery status and placement progress via tablet devices. This enabled optimization of the concrete delivery while pouring was in-progress, thereby reducing the number of waiting vehicles. Elapsed time since kneading could also be monitored, and vehicles that had exceeded a prescribed time could be immediately sent back. In the web section of the box girder, where it was difficult to check the insertion positions of vibrators and other aspects of the casting status, a small camera and tablet device were used for real-time monitoring of the casting status.

(2) Ensuring PC Grout Quality

The longest internal cable used for the superstructure concrete was 150 m. Ultra-low viscosity grout was used because high- or even low-viscosity grout would increase the risk of blockages due to excessive grout injection pressure. However, there were technical concerns about the use of ultra-low viscosity or very high fluidity grout in a downward direction, because it might cause air to be trapped at the top of the sheath and eventually impair corrosion prevention. Full-scale tests were conducted using a ribbed translucent sheath with threaded PC steel wire inside to investigate grout flow during injection, with exhaust ports at the top and at 500 mm downstream from the top. The results showed that grout in the sheath injected through the inlet gradually filled the sheath while discharging air at the top of the downward slope, and finally was discharged through the two exhaust ports without problem.

(3) Ensuring Safe Railway Operation

The form travellers used for the balanced cantilever construction of the superstructure from piers in the depot had to maintain a safety distance of 3 m from the

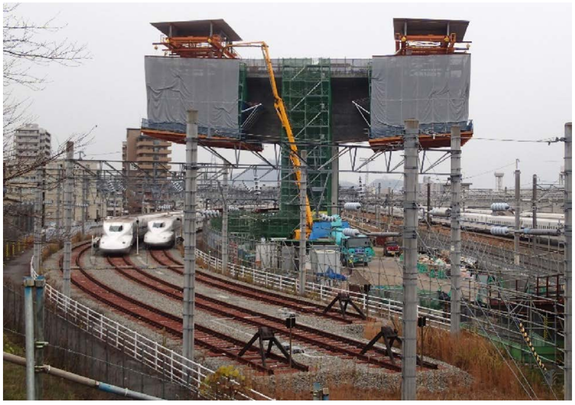

Fig. 7 Cantilever construction over the depot

25,000 V overhead power lines. This safety distance could not be obtained with conventional form travellers in which the formwork system and working platforms supporting the scaffolding are separated. Therefore, the safety distance from the power lines was obtained by integrating the formwork system with the working platforms. Assembly and disassembly of scaffolding units from form travellers over the depot poses a risk of falling objects such as concrete residues and dropped tools and materials. A safety sheet was installed on the scaffold exterior to catch any falling objects (**Fig. 7**). The sheet was suspended from the frame of the form traveller and separated from the scaffolding units, creating a work environment in which materials and equipment could not fall into the depot during any operations, including assembly and disassembly of the scaffolding units.

Fig. 8 View from the starting point

4. Conclusion

Hiroshima Expressway Route 5 is expected to improve the speed and timeliness of travel between the center of Hiroshima City and Hiroshima Airport, ease traffic congestion in the surrounding area, and promote urban development. The Yaga Overpass Bridge plays a part in these expectations, serving as a high-quality bridge constructed over the Shinkansen depot and providing an important lifeline that does not interfere with rail transportation. The completed Yaga Overpass Bridge harmonizes and integrates with the Shinkansen and rows of cherry trees on the depot's north side, creating a new landscape that will take root in the community (**Figs. 8** and **9**).

Fig. 9 View from the north

概　要

矢賀こ線橋は，橋長322m の 3 径間連続 PC 箱桁橋で，暫定 2 車線で供用される道路橋である。新幹線20編成を留置できる車両基地を横断するため，コンクリートウェブ箱桁橋としては国内最大級の中央支間長152m を有している。車両基地内の限られた敷地の中で，将来的な 4 車線化にも対応可能な基礎形式を採用するとともに，車両基地上空における長期的な維持管理に配慮した上部構造が採用されている。

施工では，コンクリートやグラウトの品質向上に対する取り組みを行ったほか，車両基地に対して安全性が確保できる設備による上部工の張出施工を行った。

車両基地北側には200m にわたる桜並木があり，矢賀こ線橋は新幹線や桜並木と調和し一体となることで，地域に根付く新たな景観を生み出した。