Deck Slab Replacement with Precast Panel “Cap Slab” for PC Composite Girders — Kamitagawa Bridge —

プレキャスト PC 床版『キャップスラブ』を用いた PC 合成桁の床版取替え — 上田川橋 —

* Kenji MITAMURA, P.E.Jp: OBAYASHI CORPORATION
三田村　健二，技術士（建設部門）:（株）大林組
** Takayuki TOMINAGA, P.E.Jp: OBAYASHI CORPORATION
富永　高行，技術士（建設部門）:（株）大林組
*** Takafumi NAKADA, P.E.Jp: OBAYASHI CORPORATION
仲田　宇史，技術士（建設部門）:（株）大林組
**** Shinya IKEHATA, Ph.D.: Central Nippon Expressway Company Limited
池端　信哉，博士（工学）: 中日本高速道路株式会社
Contact: mitamura.kenji@obayashi.co.jp

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Synopsis

The Kamitagawa Bridge required deck slab replacements due to significant deterioration after 47 years of service, with enormous amounts of deicing agents being applied to the bridge over that time. Deck slabs of precast (PCa) prestressed concrete (PC) composite girders are conventionally replaced with cast-in-place slabs, but the removal of existing slabs is time and labor-intensive, and weather conditions can make it difficult to complete on site construction within the limited times for the permitted traffic restriction. This bridge was therefore designed and constructed to shorten the construction schedule and to improve durability by replacing the deck slabs with PCa PC panels and using link slabs to form a jointless deck.

Structural Data

Structure: 4-PC simply supported girders
→Partially prestressed concrete (PPC) 4-span girders with link slabs
Bridge Length: 124.970 m
Span: 4 × 30.4 m
Width: 9.610–9.843 m
Owner: Central Nippon Expressway Company Limited
Designer: OBAYASHI CORPORATION
Contractor: OBAYASHI CORPORATION
Construction Period: Aug. 2017 – Mar. 2021
Location: Nakatsugawa City, Gifu Prefecture, Japan

1. Introduction

The Kamitagawa Bridge is composed of four numbers of simply supported composite girder bridges having span lengths of approximately 30 m, with the inbound and outbound lines in close proximity (**Fig. 1**). Its reinforced concrete (RC) slabs were severely damaged by salt and other factors and needed to be replaced, preferably with jointless slabs to improve traveling performance and prevent water leakage.

The initial plan was to replace the deck slabs with cast in place RC slabs and to convert the structure to continuous girders with the external cable reinforcement method, but a newly developed deck slab replacement

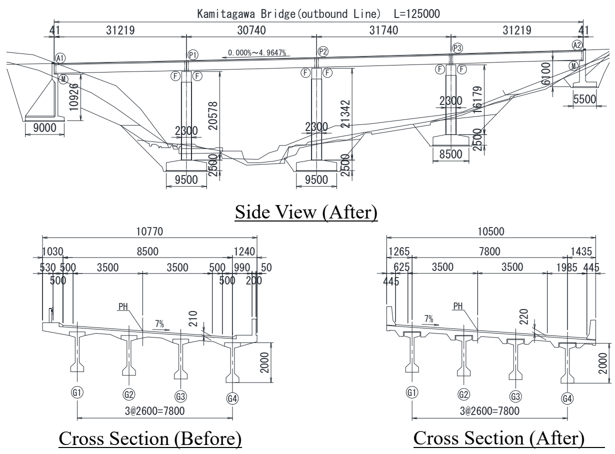


Fig. 1 General view of bridge

method using PCa PC panel “Cap Slab” was adopted to shorten the construction time.

The initial plan of using external cables for the reinforcement would require simultaneous work for slab replacement and cable installation, and a longer construction time. Therefore, link slabs were adopted to convert deck slabs to a jointless structure.

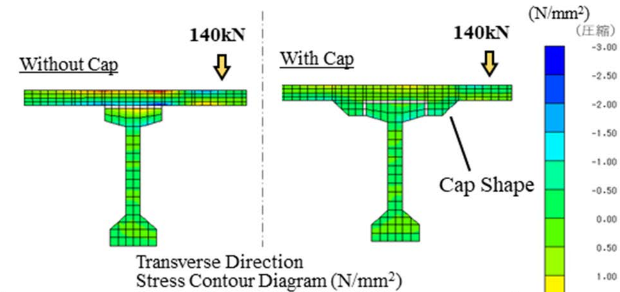
2. Design[1]

(1) Structural Design of PCa Panels

The PCa panels have a “cap” shape that covers the upper flange on existing PC girders, such that the cap portion functions as a strut against negative bending moment caused by the slab behavior. This reduces the stress generated in the slab (**Fig. 2**). This effect limits the increase in slab thickness and raises the total composite girder height, minimizing the impact on existing PC girders and abutment approaches (**Fig. 3**).

For the PCa panel fabrication, the shape, sizes and positions of the upper flange were premeasured using a 3D scanner on-site and grouped into several types, which enables better fit of PCa panel into the existing girder to maintain quality.

To make the composite section, the PC girder and slabs were connected by using post-installed anchors in upper flange and non-shrink mortar filling. The reliability of the designed structure was confirmed through full-scale tests. (**Figs. 4** and **5**).



	Overhanging Slab Fulcrum Upper Edge Stress	Stress Ratio
Without Cap	2.70	1.00
With Cap	1.30	0.48

Fig. 2 Cap shape effect (stress reduction)

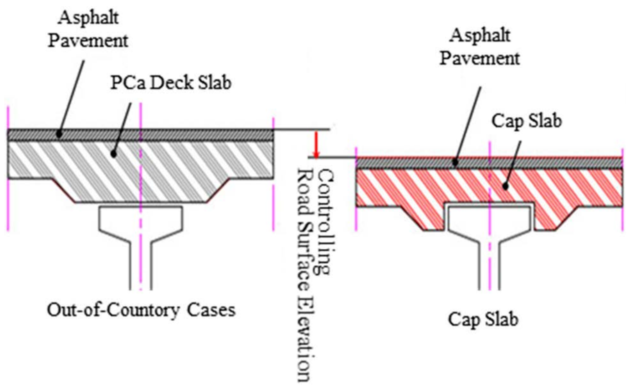


Fig. 3 Cap shape effect (deck level reduction)

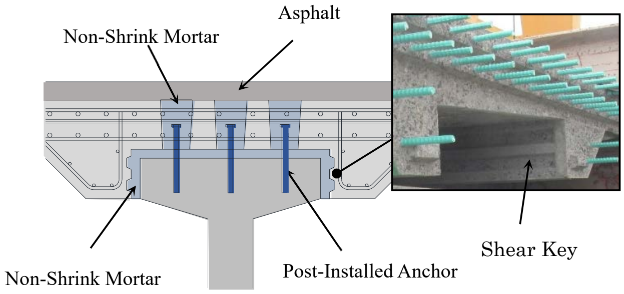


Fig. 4 Details of joints between the PCa panels and PC girders

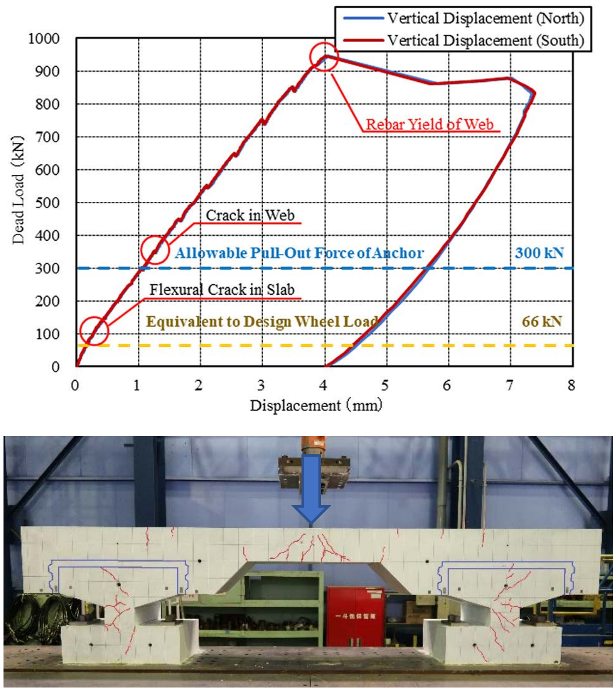


Fig. 5 Full-scale structural performance verification experiment (load transfer verification)

(2) Structural Design of Link Slab

While simply supported PC girders are conventionally converted to continuous girder with the external cable reinforcement method, in this bridge, link slabs were adopted to create a jointless bridge deck. Connection by link slabs has similar sectional force characteristics to that of simply supported girders. **Fig. 6** shows the distribution of bending moment due to a live load. As shown in the figure, negative bending moment at the piers in the girders with link slabs can be reduced by approximately 85% compared with that of continuous girders. This realizes jointless slabs without changing the behavior of the existing (simply supported girders) structure. While girders with link slabs reduce the negative bending moment at the piers, the link slab section is resisted by only the slab cross-section, and the extreme-fiber tensile stress in the longitudinal direction exceeds the tensile strength. To ensure long-term durability, concrete slabs are prestressed longitudinally to prevent cracking.

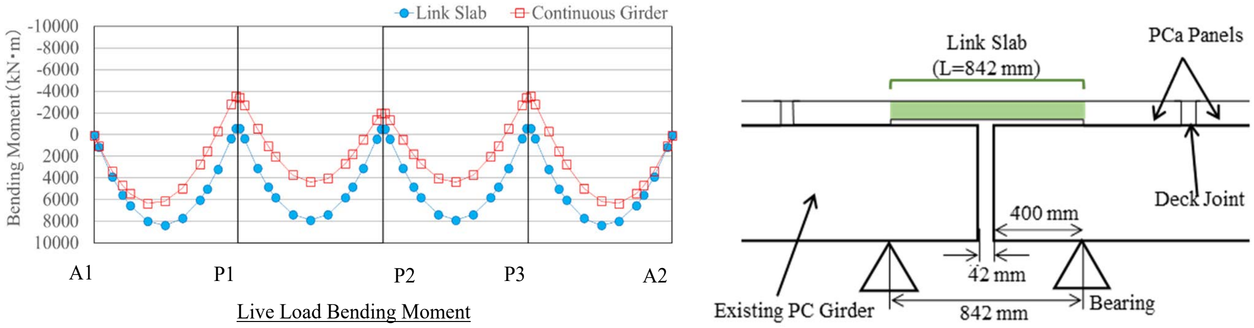


Fig. 6 Link slab (connected slab) overview

3. Construction

(1) Removal of Existing Deck Slabs

The conventional method requires concrete removal with water jets to reuse rebars in existing PC girders for composite section connections, which is time concerning work in the construction. By using the cap slabs method with post-installed anchors and non-shrink mortar, the rebars can be cut by wire saw and slabs can be removed in short-term. Existing slabs were cut and removed along the upper flange of existing PC girders using concrete cutters (vertically) and wire saws (horizontally). Steel bars from the PC girders were also cut (**Fig. 7**).

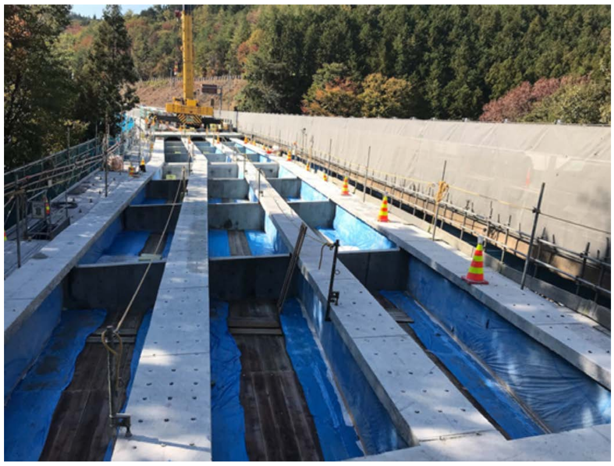


Fig. 7 Completed removal of existing slabs

(2) Erection of PCa Panels

The PCa panels were erected (**Fig. 8**), and a cementitious anchoring system was used to set shear connector rebars on the top of the upper flanges of existing PC girders. Boundary surfaces between PCa panels and upper flanges of the main girder were filled with ultra-fast-curing non-shrink mortar. Holes in the PCa panels for rebars for shear connectors were also filled with non-shrink mortar.

Fig. 8 Erection of PCa panels

(3) Deck Slab Joints

“Slim-Fastener”, a deck slab joint method using “Slim-Crete”; an ultra-high-strength fiber-reinforced concrete (UFC) that can be cured at job site, was adopted for the deck slab joints (**Fig. 9**). Longitudinal rebars were anchored in the joints. The rebars were ordinary deformed rebars with no mechanical anchoring, and the required anchorage length was five times the bar diameter, reducing the widths of joints to about 50% of those with conventional methods. Steel fibers blended in UFC eliminated the need for rebar in the transverse direction, reducing on-site work and speeding joint construction. Moreover, no existence of the transverse rebars helps the placement of shear connector by post installed anchorage even in the joints. This has the advantage of reducing the number of holes for the shear connectors in the PCa panels in comparison with conventional methods.

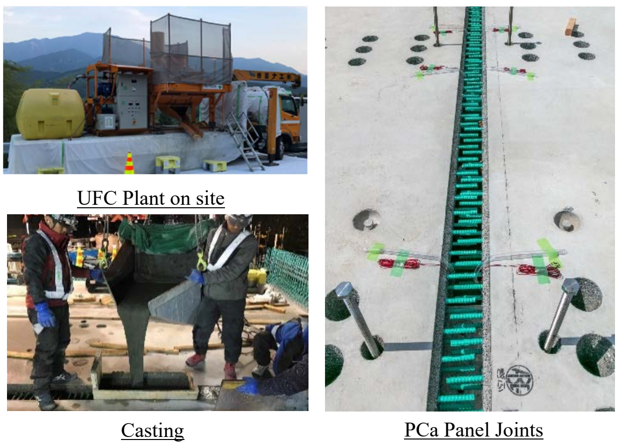


Fig. 9 Construction of PCa panels Joints

(4) Installation of PCa barrier

Fully precast Easy Maintenance & Construction ("EMC") barriers were used (**Fig. 10**). To adjust the curved plan alignment in this bridge, each EMC barrier segments were consisted of 4 m length. After installation, the PCa parapets were bolted together horizontally and bolted vertically to the deck slabs. Then, the box outs for the bolt were filled with mortar. This simple structure allows work tasks to be performed without interference from other operations. In this way, the work could be done in parallel with deck-slab joint and mortar filling operations, shortening the overall schedule.

Fig. 10 PCa barrier

(5) Schedule Shortening

The combination of the various technologies described above realized a construction speed approximately three times faster than what could be expected with conventional construction methods, shortening the total construction period for both the inbound and outbound lines by 120 days.

4. Conclusion

This article described the design and construction of a deck slab replacement using PCa panels for PC composite girders (**Fig. 11**). The implemented methods can be applied not only to the replacement of PC composite deck slabs but also to newly constructed PC composite girders, and further improvements to this method based on the knowledge obtained from this construction are planned.

In closing, the authors express their gratitude to other stakeholders for their understanding, guidance, and advice in adopting the new structure.

Fig. 11 The completed bridge

Reference

[1] Nakada, T., Tominaga, T., Mitamura, K., Suga, K., Ikehata, S., Hizukuri, M.: *Chuo Expressway Kamitagawa Bridge, Deck Slab Replacement for PC Composite Girders -Slab Replacement with PCa Panels and Continuous Arrangement by Link Slab-*, Bridge and Foundation Engineering, Vol. 53, Kensetutosho, Tokyo, pp.2-10, Nov. 2019 (in Japanese).

概　要

上田川橋は橋長125m，支間長31m×4連の PC 単純合成桁橋です。供用後47年が経過し，累積の凍結防止剤散布量も膨大で床版の劣化が著しいことから床版の更新が必要とされていました。また，走行性改善のためのノージョイント化と車両大型化対応のための既設 PC 桁の炭素繊維補強や支承取替などを実施しました。

当初，場所打ち RC 床版による床版打換えと外ケーブル補強併用による連続桁への変更を計画していましたが，既設床版の撤去と新設床版の施工は現場作業が多く，長期間の交通規制や施工日数が必要でした。そこで，PC 合成桁の床版リニューアルにおける急速施工の実現に向けて，新たに開発したプレキャスト PC 床版（「キャップスラブ」）を用いた床版取替え工法を採用しました。

さらにプレキャスト PC 床版の接合には常温硬化型 UFC を用いた床版接合工法（「スリムファスナー」），壁高欄にはフルプレキャスト壁高欄（「EMC 壁高欄」）を採用して施工の省力化と工程短縮を図ることで，従来工法に比べて約 3 倍早い施工スピードを実現し，全体で120日間もの工事期間短縮を可能としました。