Rapid Construction of Viaduct Using U-shaped Girder Lifting Erection Method — Shin-Gotemba Viaduct on Shin-Tomei Expressway —

U 桁リフティング架設工法による高架橋の急速施工 — 新東名高速道路 新御殿場高架橋 —


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Synopsis[1]

In recent years, U-shaped girder lifting erection method has been used in the construction of many multi-span continuous prestressed concrete (PC) girder bridges in Japan. Erection girders are installed on top of previously constructed pier caps, then precast girders that were fabricated elsewhere and transported onsite are erected at once per span using the erection girders, then PC panels are laid out and deck slabs are cast in place. Unlike cast-in-place construction that uses falsework, this method does not require formwork assembly and disassembly, thereby enabling onsite labor-saving and rapid construction.

Structural Data

Structure: multi-span continuous PC U-shaped composite girder bridge
Bridge length: 852.5 m + 951.0 m + 899.0 m
Span: 40.0 m (average)
Width: 10.2 m
Owner: Central Nippon Expressway Co., Ltd.
Location: Shizuoka Prefecture, Japan

1. Introduction

In recent years, U-shaped girder lifting erection method has been used in the construction of many multi-span continuous PC girder bridges in Japan. In this method, precast girders are transported to the span location and erected at once per span using erection girders. The large-scale bridge project reported herein involved 139 spans across three bridges of inbound and outbound lanes that had to be completed within a specified construction period, and the aforementioned method was used because of its time-tested high productivity and to make the most of the close proximity of similar bridges with the same construction cycle. This paper presents various measures to further improve productivity and shorten the construction schedule.

2. Overview of Project

(1) Bridge Description

The Shin-Gotemba Viaduct on the Shin-Tomei Expressway comprises three 900-m-long multi-span continuous PC girder bridges, the specifications of which are given in **Table-1**. The overall plan is shown in **Fig. 1**, and a typical cross section is shown in **Fig. 2**. The standard span length is 40.0 m, with a maximum span length of 43.0 m at the road crossing. Because the entire bridge is located on flat terrain, the substructures are low piers with heights of 5.5–13.7 m, with separate structures for inbound and outbound lanes. Both the inbound and outbound lanes are bridges with an effective width of 9.5 m and two box girders with a constant depth of 2.6 m. The horizontal alignment changes successively across all the bridge spans, with the transverse slope changing from −2.5% to +2.5% for each bridge.

Table-1 Bridge specifications

Project		Designer & Contractor	Number of Span	Length (m)	Max. Span Length (m)	Effective Width (m)
Suginazawa-daiichi viaduct	Inbound lanes	Sumitomo Mitsui Construction・Nippon P.S・ Kyokuto Kowa Joint Venture	23	852.5	40.0	9.50
	Outbound lanes		23			
Gumizawa-simo viaduct	Inbound lanes	Sumitomo Mitsui Construction・Nippon P.S・ Kyokuto Kowa Joint Venture	24	951.0	41.0	9.50
	Outbound lanes		24			
Gumizawa-kami viaduct	Inbound lanes	Sumitomo Mitsui Construction・Kawada Construction DPS Bridge Works Joint Venture	22	899.0	43.0	9.50
	Outbound lanes		23			
Total			139	2702.5×2	(Inbound and Outbound lanes)	

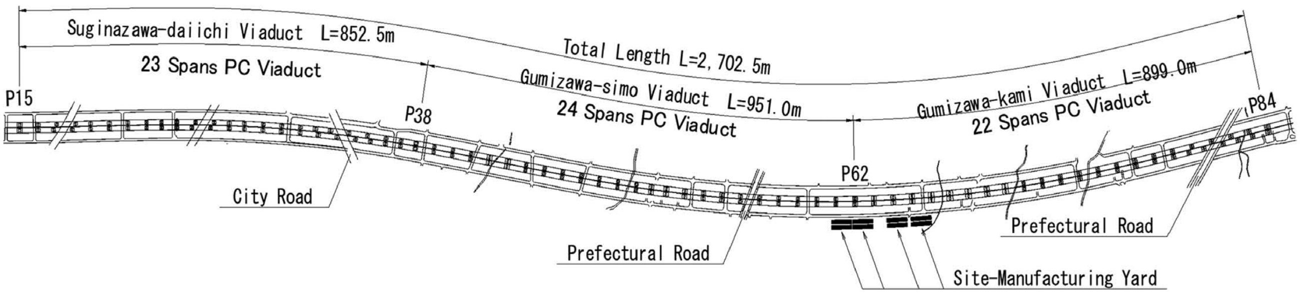

Fig. 1 Overall plan

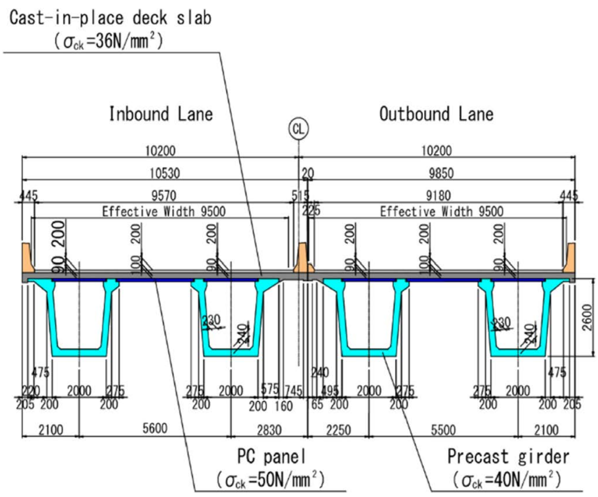

Fig. 2 Typical cross section

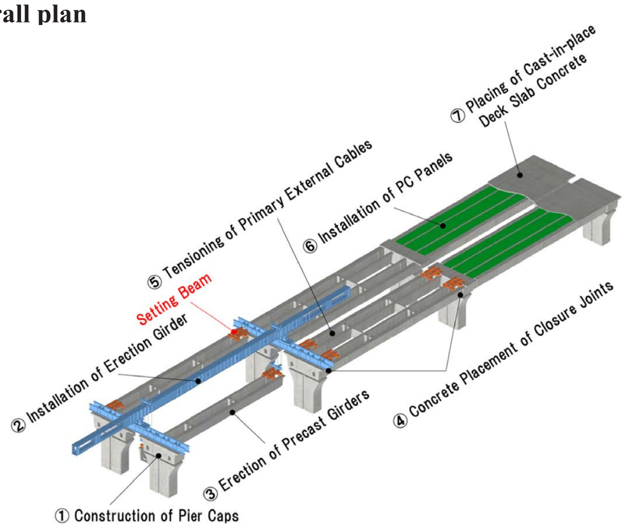

Fig. 3 Construction procedure

(2) Construction Overview

The bridge was erected using U-shaped girder lifting erection method, in which precast girders with a U-shaped cross section were erected at once per span using erection girders. This method is suitable for constructing continuous large-scale viaducts with relatively uniform spans and girder depths. Each cast-in-place deck slab is a composite structure that uses PC panels as embedded concrete formwork for streamlined construction and improved quality.

Fig. 3 shows the construction method, the procedure of which is as follows: (i) construction of pier caps, (ii) installation of erection girder, (iii) erection of precast girders, (iv) concrete placement of closure joints, (v) tensioning of primary external cables, (vi) installation of PC panels, and (vii) placing of cast-in-place concrete deck slabs. The precast girders for one span were fabricated in one batch at the casting yard (near P62 in **Fig. 1**) on the construction site, transported to the erection site using platform trailers, and erected using a lifting erection girder.

3. Features of U-Shaped Girder Lifting Erection Method

As discussed in Section 2-2, this method erects precast girders at once per span using an erection girder. Thus, compared to cast-in-place construction using falsework, this method does not require formwork assembly and disassembly, thereby enabling onsite labor-saving and rapid construction. Moreover, the method does not require a stockyard for precast girders because the construction continuously cycles through precast girder fabrication and erection in the same number of days. Thus, the key is to reduce the number of days in the erection cycle while maintaining the just-in-time production.

4. Strategies for Rapid Construction

(1) Production of Half-precast Pier Caps

The entire bridge has 142 pier caps, which had to be constructed in advance so that they would not interfere with the schedule of precast girder erection. Therefore, a half-precast segment structure in which the outer shell comprised of girder webs and thin-walled, reinforced crossbeam was adopted to shorten the construction process and ensure construction quality. After erecting the pier cap segments, they were joined to bearing supports previously installed during erection and temporarily fixed by installing temporary support bases to prevent them from falling. Then, the deviator ducts for external cables and reinforcing bars were assembled inside the outer shell, and concrete was cast into the box-shaped pier cap members, as shown in **Figs. 4** and **5**. This simplified the formwork, thereby enabling onsite labor-saving and shortening the work schedule.

Fig. 4 Erection of a pier cap segment

Fig. 5 Assembly inside a pier cap segment

(2) Simplification of Precast Girders

For this project, the precast girders were fabricated on eight casting beds at the site-manufacturing yard located beside the bridge between P61 and P66 (**Fig. 1**) on the construction site. Roofing was provided over the casting beds so that the weather would not affect the construction cycle (**Fig. 6**).

The entire bridge required 278 precast girders to be produced, therefore the precast girder structure was simplified for increased productivity and fewer cycle days for precast girder fabrication. **Fig. 7** compares the conventional structure and that used for this bridge project. In the conventional structure, the external cable deviators require a manhole in the diaphragm, whereas for this bridge, a ribbed structure was used to facilitate the installation and removal of formwork during production; the ribbed structure provides larger openings and better passage during maintenance (**Fig. 8**). Furthermore, the conventional structure has diaphragms at lifting points to reduce deformation when lifting the precast girders, whereas for this bridge, the diaphragms were eliminated to simplify the inner formwork and reinforcement arrangement.

Fig. 6 Site-manufacturing yard

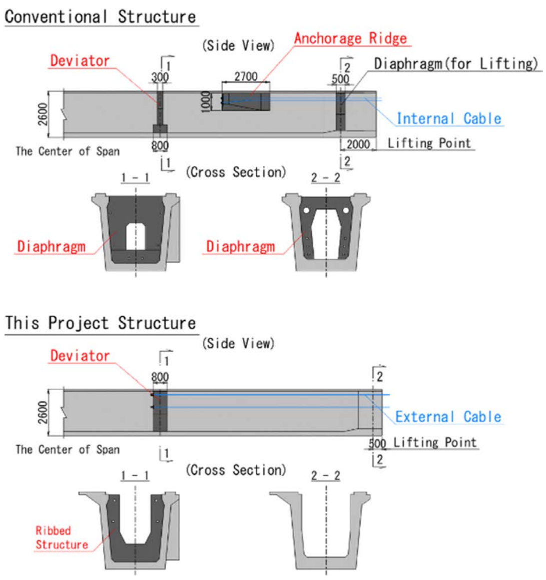

Fig. 7 Comparison of precast girder structures

Fig. 8 Simplification of precast girder

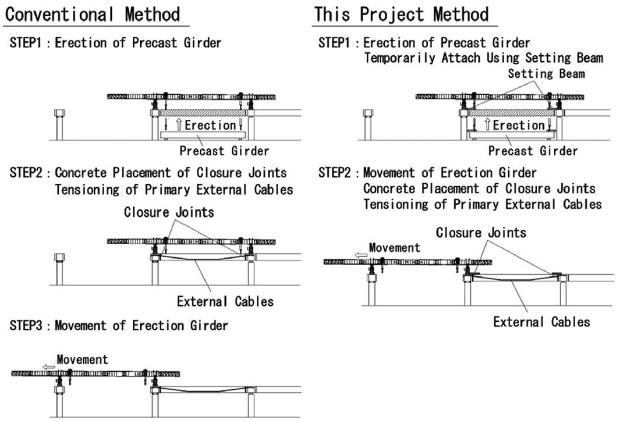

Fig. 9 Comparison of erection methods

Fig. 10 Replacement with setting beam

(3) New Erection Method in Conjunction with Setting Beams

Fig. 9 compares the conventional erection method and the new method used in this project. In the conventional method, the erection girder cannot erect the next precast girder until the external cables have been tensioned and the precast girder is connected to the pier caps, requiring more erection girders to reduce the number of cycle days. Therefore, this project used an erection method that allows the erection girder to be moved immediately; after lifting the precast girder, the erection girder is replaced with setting beams that temporarily hold the girder on top of the pier caps (**Fig. 10**). This made it possible to reduce the number of cycle days for erection without increasing the number of erection girders. Note that hydraulic jacks installed on top of the pier caps were used to fix the beams temporarily; four jacks with a capacity of 100 tons each were used for each girder.

5. Conclusion

In the past, U-shaped girder lifting erection method has been used to shorten the work schedule when constructing multi-span continuous PC girder bridges. This paper described measures to further improve productivity and shorten the construction schedule on a continuous PC U-shaped composite girder bridge, including simplifying the precast girders and conducting at once per span erection in conjunction with setting beams.

The bridge project was completed in December 2020, and the expressway between the Shin-Gotemba Interchange and Gotemba Junction including the bridge in this study was opened successfully in April 2021 (**Fig. 11**).

Fig. 11 Completion view

Reference

[1] Hirano, Y., Kaminaga, Y., Yamaguchi, T., Takagi, H.: *Rapid Construction of A Composite Bridge Using the U-Girder Lifting Erection Method*, Proceedings for the 6th fib International Congress, Oslo, pp.913-919, June. 2022.

概　要

新東名高速道路 新御殿場高架橋は，新御殿場 IC ～御殿場 JCT 間に位置する 5 連の高架橋で，本橋はそのうち総延長約2.7km の 3 連の多径間連続桁橋であり，構造形式はいずれも PC 連続 U コンポ橋である。

本橋は， 3 橋の上下線で合計139径間ある大規模橋梁であり，決められた工期内で完成することが求められるなか，同種の橋梁を施工する隣接した工事であることの利点を最大限活かすために，現場内で製作したプレキャスト桁を運搬し，架設ガーダーによって一括架設する U 桁リフティング架設工法の更なる合理化に取り組んだ。柱頭部のハーフプレキャスト構造化，プレキャスト桁の構造の簡素化，架設ガーダーとセッティングビームの併用を採用することによって，ひとつの桁の製作から架設までの工程短縮を実現した。