Design and Construction of Pretensioned-Precast Web Bridge
— Nakashinden Viaduct —

プレテンションウェブ橋の設計・施工
— 中新田高架橋 —




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Synopsis
The Nakashinden Viaduct is a multi-span continuous bridge located in the south side of the Ebina Interchange on the Metropolitan Inter-City Expressway. Pretensioned-precast webs were adopted in this viaduct for the purposes of labor saving at the site and reduction of the construction period. This is the first pretensioned-precast web bridge constructed with falsework in Japan.
This report describes the design and construction of the Nakashinden Viaduct with pretensioned-precast webs.

Structural Data
Structure: Multi-span continuous prestressed concrete twin-box girder bridge
Bridge Length: Inbound line: 958 m
Outbound line: 991 m
Span: 9 × 41.0 m; 8 × 41.0 m + 2 × 32.5 m + 2 × 30.5 m + 43.0 m + 34.0 m + 2 × 33.0 m
Width: 11.400 m – 21.050 m
Owner: Central Nippon Expressway Co., Ltd.
Designer: P.S. Mitsubishi - Shimizu JV
Contractor: P.S. Mitsubishi - Shimizu JV
Construction Period: Nov. 2005 – Nov. 2009
Location: Kanagawa Prefecture, Japan

1. Introduction
The Nakashinden Viaduct is a multi-span continuous bridge located in the south side of the Ebina Interchange on the Metropolitan Inter-City Expressway (Ken-O Expressway) (**Fig. 1**). This viaduct is a part of the Ken-O Expressway and also constitutes the Ebina Junction which links to the Tomei Expressway. The bridge was expected to be opened to traffic as early as possible to improve the local traffic flows and reduce environmental loads. In order to meet such demands, pretensioned-precast web structure was adopted for reducing construction period as well as self weight. This bridge was constructed using falsework, and this was the first application of this construction method to a pretensioned-precast web (hereinafter referred to as "PPW") bridge in Japan.

Fig. 1 Overview

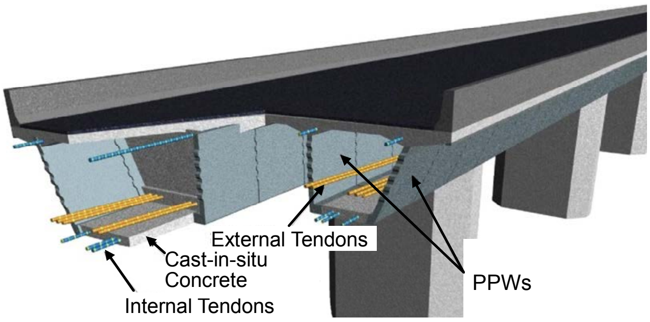

Fig. 2 Perspective of the main girder

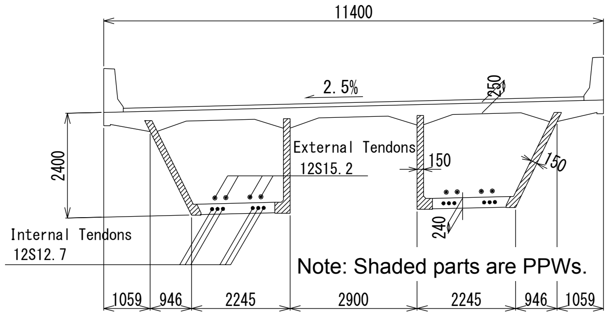

Fig. 3 Girder cross section

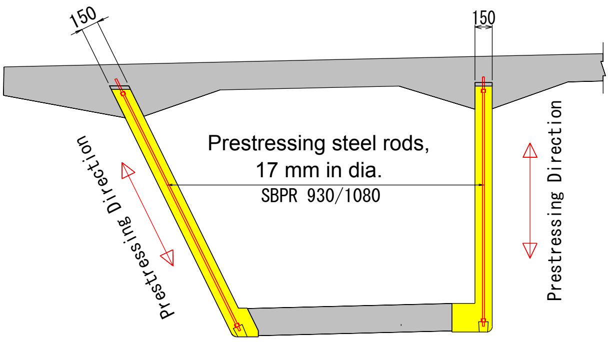

Fig. 4 PPW cross section

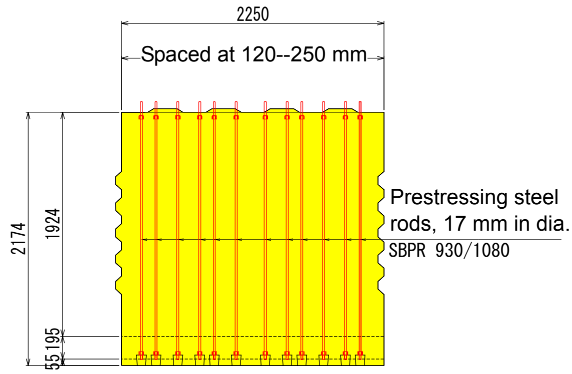

Fig. 5 PPW side view

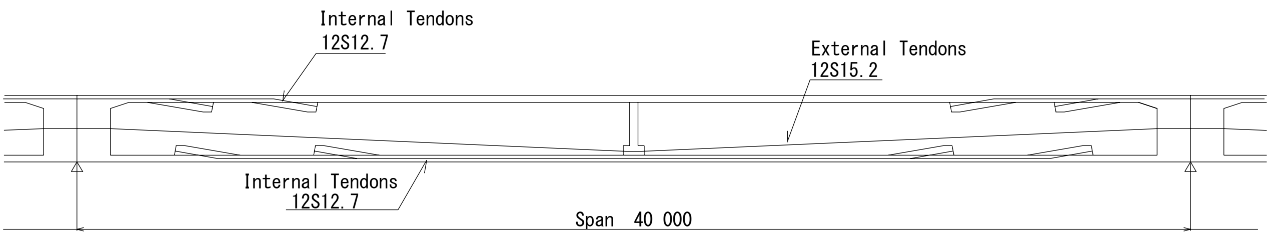

Fig. 6 Tendon arrangement

A PPW bridge is a box girder bridge with pretensioned prestressed precast concrete webs. The use of precast webs saves labor at site and improves work efficiency, achieving a large reduction in construction period. In addition, PPWs can be designed in thinner thicknesses due to its high shear resistance, which greatly saves the superstructure weight. This structure is expected to provide rationalization in construction and maintenance of concrete box girder bridge.

2. Design

(1) General Structure

The outline of the Nakashinden Viaduct is shown in **Figs 2** to **5**. This bridge has a cross section of twin-box girder. PPWs are used for all of four webs in an attempt to reduce work in the field for a shortened construction period as well as to make the web thickness thinner for a reduced superstructure weight. No large-scale facilities are needed unlike a construction system with entirely segmented main girders. There is no restriction in selecting a transport route from a factory to a site. Another advantage is the flexibility to a varying horizontal alignment including widening.

As shown in **Fig. 4**, the PPWs are embedded in the upper slab and directly connected to the lower slab at the bottom. This joint system was selected for the ease of construction using falsework.

Longitudinal tendons are placed both internally and externally. Internal tendons of SWPR7B 12S12.7 are placed in the upper and lower slabs. SWPR7B 12S15.2 is used for external tendons (**Fig. 6**).

Prestressing steel rods used in the PPWs are round bars of SBPR 930/1080 with a diameter of 17 mm. Nuts are mounted on the bars to shorten the development length (**Fig. 5**). The PPW thickness is 150 mm in standard sections and 200 mm or 250 mm around the supports where shear stress is relatively high.

(2) Joint between the PPWs and Upper Slab

The PPW joint structure has no lateral shear keys as shown on the right side of **Fig. 7**. The reason for this is that concrete lateral shear keys require floating forms in

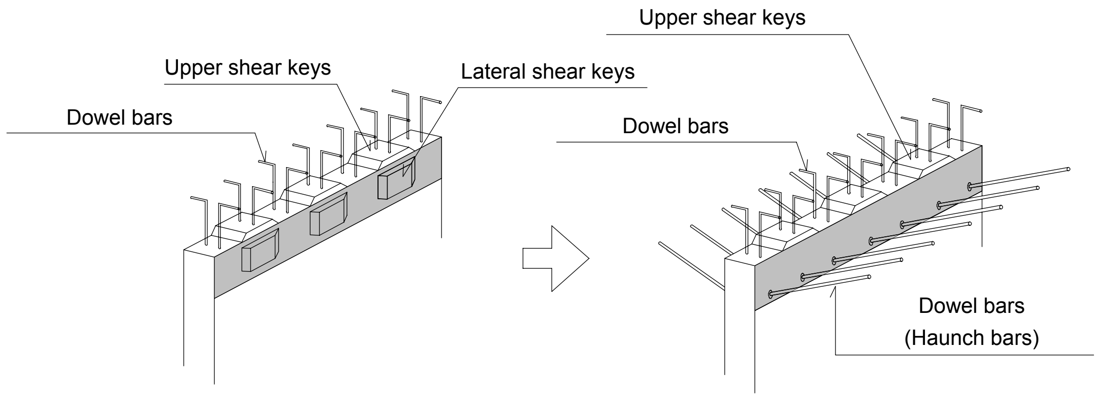

Fig. 7 PPW joint structure

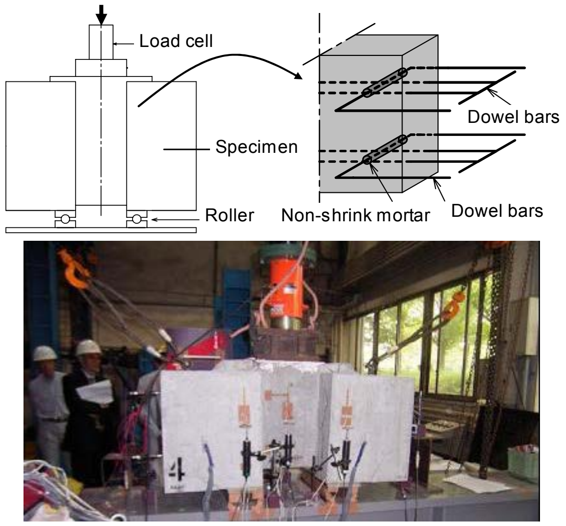

Fig. 8 Double shear test

Fig. 9 Test specimens (before placing concrete)

manufacturing the web members at a factory, making the work complicated. The dowel bars provide the sides of the web with a similar shear transfer interface to that provided by lateral shear keys. A double shear test was conducted as shown in **Fig. 8**, and it was verified that the design shear transfer capacity was achieved successfully. [1].

(3) Prestressing steel rods in the PPWs

In the PPWs prestressing force is required in such locations extremely close to the edges of the web member at the base of the connection with the upper or lower slab. Methods available for improving bond anchorage at the edges include: 1) installation of compression grips or nuts on steel rods or strands; and 2) use of deformed steel bars with high bonding performance. In order to select prestressing steel, bond anchorage performance test was conducted (**Fig. 9**). Based on the results [1], it was decided to adopt the combination of round steel and nuts which showed sufficient bonding performance at the edges. The rod ends were threaded to make the nut installation easier and thus this combination more productive than that of strands and compression grips.

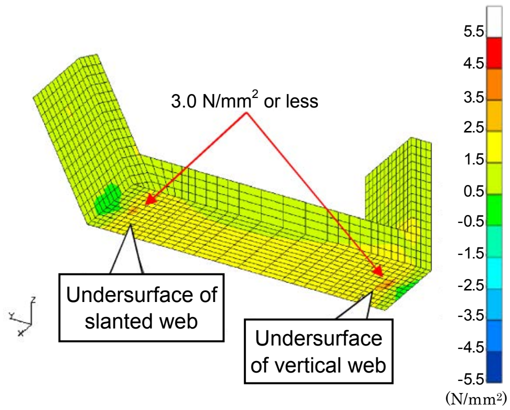

Fig. 10 FEM analysis

(4) Analytical verification on the PPW joints

The construction joints of the PPWs with the bottom edge of the main girder may open under tensile force, causing cracks intensively around them. In order to confirm the stress state in the lower slab near the joints under tensile force, FEM analysis was conducted using a model capable of evaluating the opening behavior of the PPW joints [1].

The analysis results showed that local tensile stress in the cast-in-place slabs near the PPW joints under primary loads would not be larger than 3.0 N/mm^2 (**Fig. 10**), suggesting there would be no harmful stress concentration to the structure.

3. Construction

(1) Manufacturing of the PPWs

The number of PPWs to be manufactured for this bridge amounted to as many as about 4000. Therefore, a long-line separate manufacturing system which could simultaneously process eight webs per line was used (**Fig. 11**) [2].

The weight of each single PPW was about 25 kN which was determined in consideration of factory manufacturing, transportation, and the lifting capacity of a truck crane to be used at the site.

(2) Construction of the PPW bridge

Figs 12 and **13** show the views of construction.

Split construction method was adopted for this project, with the total construction length of about 2 km divided by every two spans. Steel bars and brackets were used for pulling the PPWs as well as for preventing falling of the PPWs [2].

The use of PPWs enabled reduction of work required in the field such as web construction, successfully shortening the construction period by about 20% as compared to conventional cast-in-place construction using falsework.

Fig. 11 Manufacturing of the PPWs

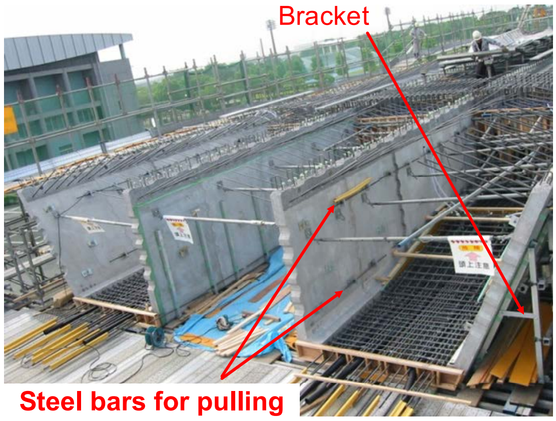

Fig. 12 Setting up the PPWs

Fig. 13 Cross section

4. Conclusion

PPWs were used for the construction of the Nakashinden Viaduct, with the superstructure weight and construction period reduced substantially. The bridge was completed in November 2009 and opened to traffic in February 2010. The authors hope this report would be of help for increased application of the PPW bridge system in future.

The authors express their appreciation to all related parties who cooperated in this project.

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概　要

中新田高架橋は，首都圏中央連絡自動車道の海老名 IC 南側に位置する連続高架橋である。主桁断面は 2 主箱桁断面であり，プレテンションウェブ構造を採用している。プレテンションウェブ橋は，箱桁橋のウェブ部材に，プレテンション方式によりプレストレスを導入したプレキャスト部材を採用した構造で，現場施工の省力化，工期短縮および自重の低減が可能な構造である。本橋は固定支保工による施工であり，この工法でのプレテンションウェブ橋は国内で初となる。本橋は2009年11月に完成し，2010年 2 月に供用が開始されている。

本稿は，プレテンションウェブ橋を採用した中新田高架橋の設計および施工について報告するものである。