Rationalization of Construction of a Long-span Bridge — Yobaisan Viaduct on Shin-Meishin Expressway —

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Synopsis[1], [2]

The Yobaisan Viaduct on the Shin-Meishin Expressway in Japan comprises two continuous partially prestressed concrete bridges, each of which is over 1100 m long. Each box girder comprises concrete webs and corrugated steel webs. The maximum girder height of 12 m and cantilever length of 86.4 m in the corrugated steel web sections are of the world's largest class for a girder bridge constructed by the cantilever erection method. Each bridge splits into main and ramp sections near the east end (Kyoto side) for a junction with another road, becoming gradually wider from 11.40 m to 24.95 m (westbound) by increasing the number of main girder cells from one to three eventually. Measures taken to streamline construction of this large-scale complex structure included (i) using high-strength prestressing steel as external tendons for fewer tendons and (ii) partial prefabrication of the reinforcement of the pier head cross beams in the corrugated steel web sections. Simplified form travellers enabled simultaneous work on multiple cantilever blocks resulting rapid and efficient cantilever erection.

Structural Data

Eastbound (Westbound)
Structure: 12(11)-span continuous box girder bridge
Bridge Length: 1106.5(1116.5) m
Span Length: main 90.5(100.0) m, max 125.0(155.4) m
Width: 11.50(11.40) to 24.93(24.95) m
Girder height: 3.0 to 12.0 m

1. Overview of the Viaduct

The Yobaisan Viaduct on the Shin-Meishin Expressway is located in Takatsuki City, Osaka Prefecture, Japan. It comprises two continuous partially prestressed concrete bridges, each of which over 1100 m long, and the box girders of each bridge comprise concrete webs and corrugated steel webs (CSWs). Each bridge splits into a main bridge and a ramp near the east end to form part of a junction. The standard bridge width (11.50 m or 11.40 m) is constant from the west end until pier UP4 on the eastbound bridge and around pier DP5 on the westbound bridge and then gradually increases to accommodate the main and ramp sections. The number of girder cells increases from one to two in the eastbound UP4-UP3 section and in the westbound DP5-DP4 section and from two to three in the eastbound UP3-UP2 section and the westbound DP3-DP2 section. The number of cells changes at the midspan cross wall at the closure point. Each of the 3-cell box girders then splits into the main and ramp sections at the east end of the support cross beam of pier UP1 on the eastbound bridge or pier DP1 on the westbound bridge.
The web structure changes from concrete webs to CSWs in the spans on the east side of piers UP1 and DP1 on both the main and ramp sections, with the webs of different types connected via the midspan cross walls (**Figs. 1** and **2**).

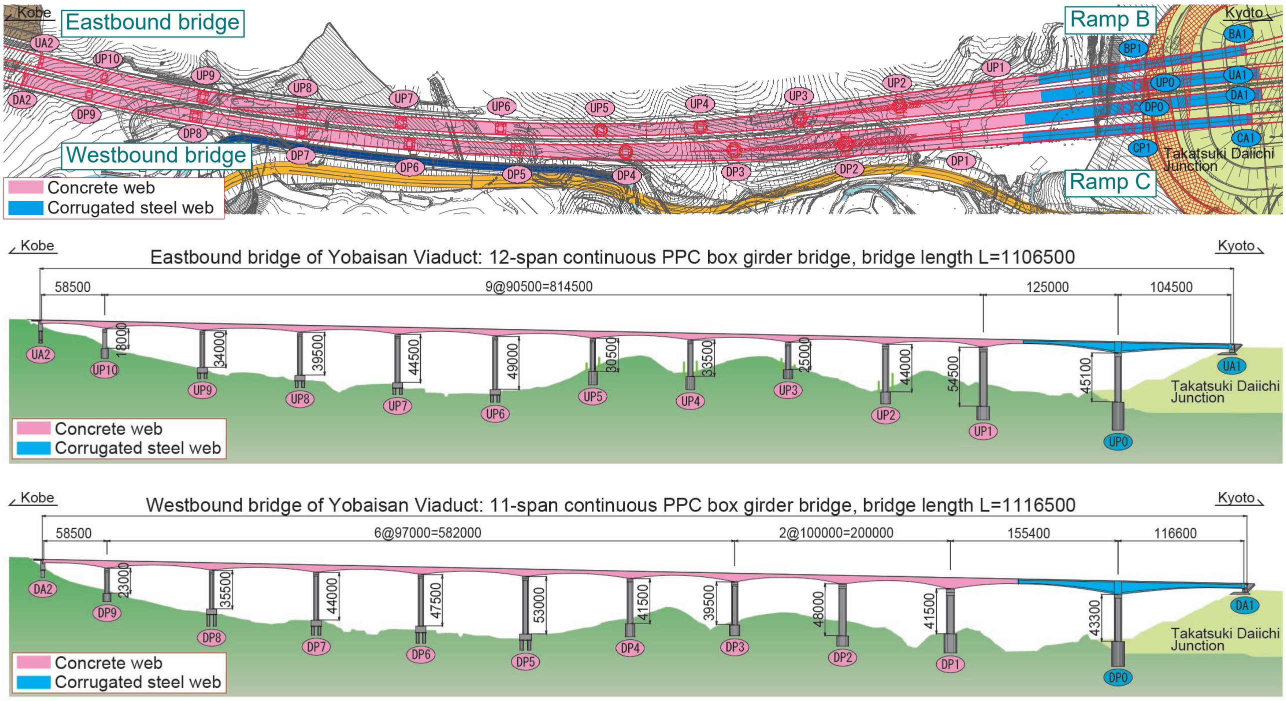

Fig. 1 General views

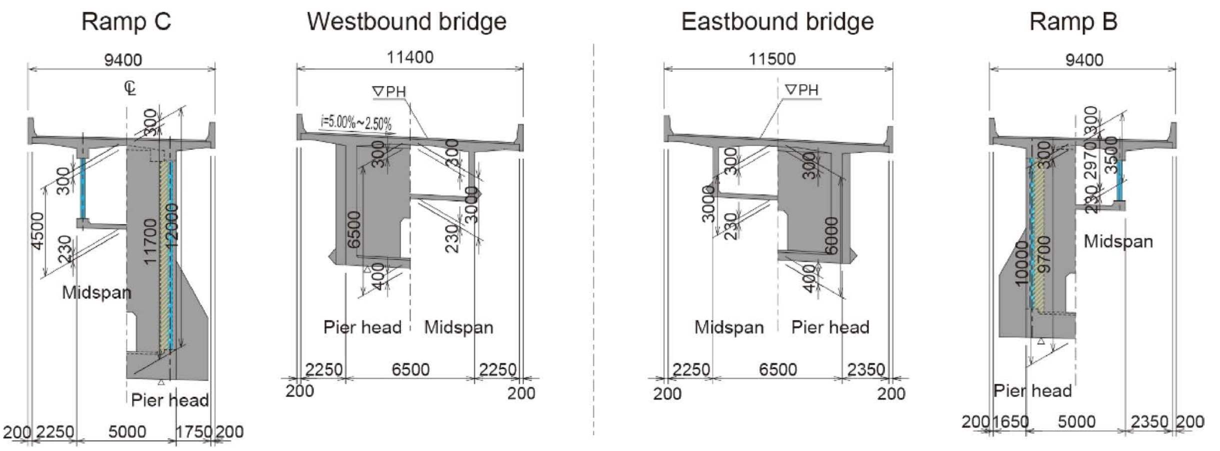

Fig. 2 Standard cross-sectional views

2. Design and Construction

(1) Cantilever Erection

The width of the viaduct was changed by altering the cross-sectional shape, with the numbers of webs changing at the midspan cross walls as described above. For ease of operation of form travellers, the multiple cell sections have irregular web intervals; that is, the web interval for one of the two cells or two of the three cells was fixed, and that for the remaining one cell was left variable. **Fig. 3** shows the construction of pier UP3 for reference.

The number of webs changes at the middle of a span, not at a pier head, and thus is equal for the right and left sides of each pier. Although this made it relatively easy to arrange the tendons required for cantilever erection, structural discontinuity arose in the webs within a single span. The authors examined possible influences of these characteristics, focusing on the following: (1)

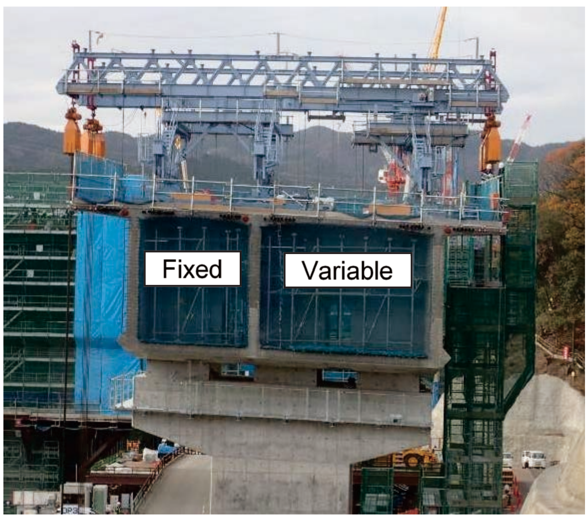

Fig. 3 Construction of pier UP3

influence of the irregular web intervals on load sharing, and (2) influence of the local stress that would occur near the midspan diaphragms where the numbers of webs change.

Finite-element analysis was conducted to ensure structural safety regarding these issues, and it was found that differences from several evenly distributed loads would be up to 10% in the 2-cell section and 15% in the 3-cell section. Based on the results, uniform load addition rates were applied, namely, 10% to the 2-cell section and 15% to the 3-cell section, and a minimum thickness of 600 mm was ensured for the diaphragm as a countermeasure, which was confirmed to be effective in keeping the stress to the minimum without affecting structural integrity. The connection between the concrete-web and CSW structures was also made via the midspan diaphragms, changing the cross-sectional shape.

Because of the very tight schedule, it was necessary to carry out cantilever erection simultaneously at 21 piers in 30 months, with up to 32 form travellers in operation at a time during the tightest period (**Fig. 4**).

Fig. 4 Cantilever erection at multiple piers

(2) High-Strength Prestressing Steel

The span length of the viaduct is up to 100 m in the concrete web sections, and future width expansion into the permanent shape is planned for the viaduct. This requires many permanent external tendons to be installed, which inevitably results in dense reinforcement and multi-tier arrangement of the deviators. To prevent possible structural problems or reduced construction efficiency, epoxy coated and filled (ECF) strands 19S15.7 were used for the permanent external tendons in place of the initially selected normal-strength strands 19S15.2.

An ECF strand, which is 30% stronger than a normal strand, is a corrosion-proof prestressing steel strand coated with high-quality epoxy powder (coating film: 400–1200 μm) that provides improved anti-fatigue properties and higher corrosion resistance compared to ordinary prestressing steel strands. Furthermore, ECF strands can be used for external tendons without grouting, which reduces labor and time requirements during construction, reduces the weight of the tendons in design, and makes inspecting the tendons easier when the viaduct is in service. **Fig. 5** shows a schematic of an ECF strand. The number of tendons was reduced successfully by about 30% by using the high-strength 19S15.7, and **Fig. 6** shows the arrangement of the external tendons at the deviators.

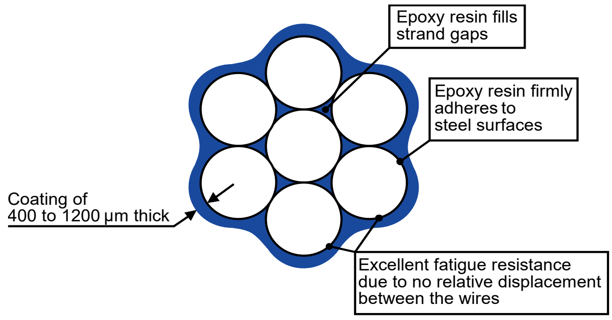

Fig. 5 Schematic of ECF strand

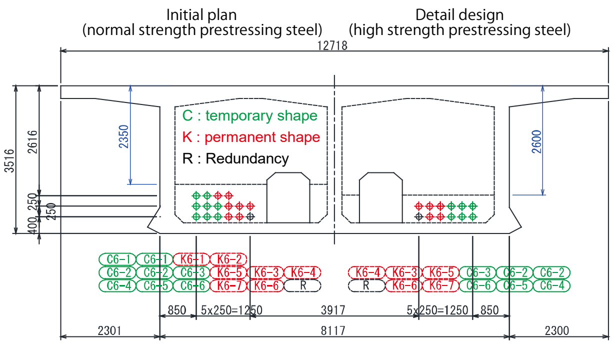

Fig. 6 Comparison of deviator part

(3) Prefabricated Reinforcement

The girder height at the pier head is 10 m on BP1 and 12 m on CP1, and concrete placement by four lifts was initially planned for those pier heads. To shorten the work schedule, it was decided to partially prefabricate the reinforcement for the second and third lifts and perform block erection on these piers.

Fig. 7 Erection of prefabricated reinforcement

The prefabricated reinforcement was assembled at an assembly yard located near pier CP1 using the lifting equipment (200-ton class cranes) as initially planned. The reinforcement block for pier CP1 was erected directly from the assembly yard using the cranes. The reinforcement block for pier BP1 was transported from the yard to sit by a 15-ton truck and then erected (**Fig. 7**). The positions of the steel bar joints were changed for the prefabrication of reinforcement. Using prefabricated reinforcement helped shorten the construction period by eight days on each pier.

(4) Rapid Construction Method for CSWs

CSWs were used for the two long spans (up to 155.4 m) on the east end on each of the main bridges and ramps to reduce the self-weight. In usual cantilever erection of a CSW bridge, it is difficult to carry out installation of the corrugated steel plates and concrete placement of the lower and upper deck slabs simultaneously because these processes are performed at the same location. One of the countermeasures to face these difficulties was to use simplified lifting frames for the erection as shown in **Fig. 8**.

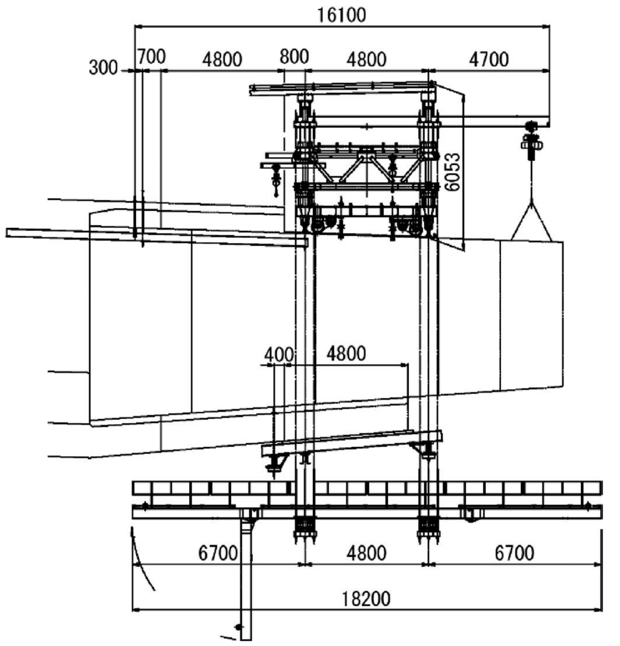

Fig. 8 Lifting frame for rapid construction method

These lifting frames are travelling on rails laid on the upper flange of CSWs. The top concrete slab and the 22 mm thick upper flange of CSWs are connected by the angle dowel connection to attain sufficient resistance against forces induced by the erection. The work schedule was shortened successfully by about 50 days per pier on the viaduct, which had long cantilever lengths and many blocks.

3. Conclusion

This paper describes various measures taken in the design and construction of the Yobaisan Viaduct for on-schedule completion of the project with hard-to-handle structural features. Detailed design of the project began in January 2013, and construction of the large-scale bridges (over 1100 m long) with a complex structure had to be carried out under tight restrictions and difficult conditions. The viaduct was completed in 2019, five years and three months after the start of pier head construction in September 2014 (**Fig. 9**).

Fig. 9 Completion view

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概　要

楊梅山高架橋は，新名神高速道路の高槻 JCT・IC の西側に位置する多径間連続箱桁橋で，コンクリートウェブ構造および波形鋼板ウェブ構造で構成されている橋長1100m を越える大規模橋梁であり，本線部とランプ部に分岐するため，幅員の変化にともない箱桁の室数が変化する複雑な構造を有している。本工事では先行工事が構築した下部工の引き渡し時期や隣接する土工区間との調整など施工面で多くの制約が生じていたが，定められた工期を満足しながら品質を確保するために，高強度 PC 鋼材の使用，柱頭部でのプレファブ鉄筋や波形鋼板ウェブ部での特殊な急速施工方法の採用などを実施して合理化を進めた。