Design and Construction of Butterfly Web Bridge
— Takubogawa Bridge —

バタフライウェブ橋の設計と施工
— 田久保川橋 —

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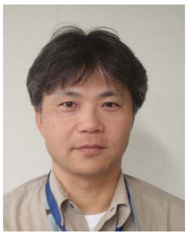 ***
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Synopsis
Takubogawa Bridge (**Figs.1, 2 and 3**) is a 712.5m-long ten-span continuous prestressed concrete box-girder bridge located between Hyuga Interchange and Tsuno Interchange on the Higashi-Kyusyu expressway in Miyazaki Prefecture.
This is the first application of concrete precast “Butterfly Web” panels, which are fabricated in a butterfly shape. Compared to conventional concrete box-girder structure, this unique structure enabled to reduce the dead load of the superstructure by approximately 10%. And a decrease in construction costs is expected through the reduction of both prestressing steel weight and amount of bearing supports.
The cantilever method was used for the main girder, where the decreased dead load of the webs allowed the establishment of 6m-long construction unit, and the resulting decrease in the number of units led to a shortened the construction process.

Structural Data
Structure: 10-span continuous butterfly web bridge
Bridge Length: 712.5m
Span: 58.6m + 87.5m + 7@73.5m + 49.2m
Owner: West Nippon Expressway Co., Ltd.
Designer: Sumitomo Mitsui Construction Co., Ltd.
Contractor: Sumitomo Mitsui Construction Co., Ltd.
Construction Period: Aug. 2010 – Aug. 2013
Location: Miyazaki Prefecture, Japan

Fig.1 Takubogawa Bridge

1. Introduction
It is important to reduce the superstructure weight in the earthquake prone country like Japan. Therefore, corrugated steel web bridges have been applied in many projects. However, the composite structure of steel components and of their joints with the concrete in these bridges produces a requirement for special machining technology and for on-site welding. The new type of structure “Butterfly Web” reported in this paper was devised for the purpose of resolving this sort of issue with composite bridges. It can meet the requirement of light weight and make it possible to shorten the construction process. Takubogawa Bridge

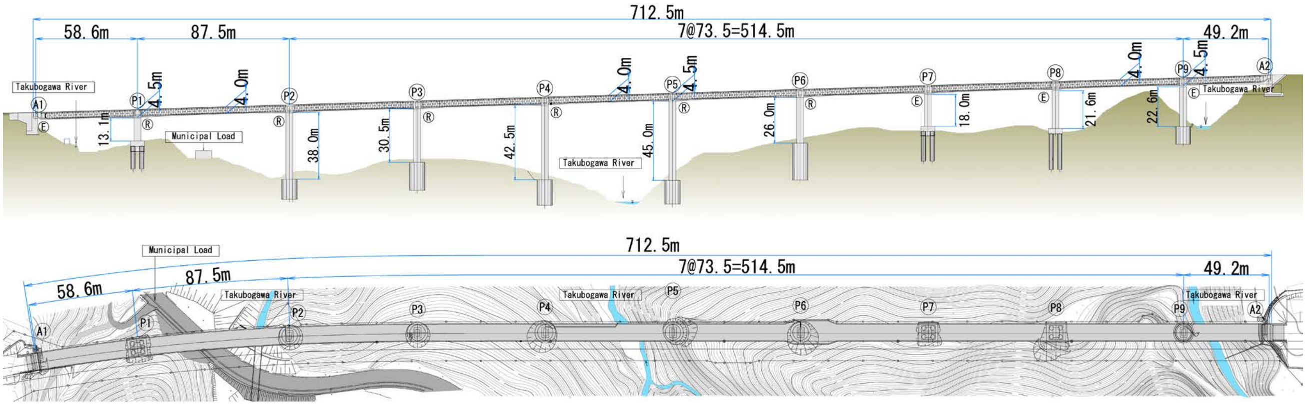


Fig.2 General view of Takubogawa Bridge

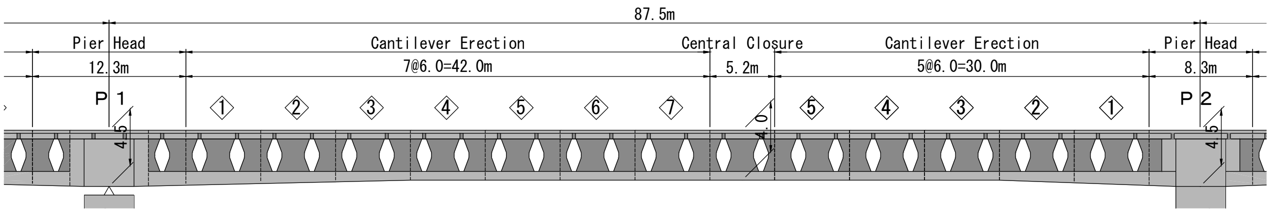


Fig.3 Side view of maximum length span

is the first application to use a butterfly web structure.

2. Design of Takubogawa Bridge

(1) Butterfly Web

The butterfly web structure uses butterfly-shaped panels in the web. With respect to shear force acting on the web, it behaves similarly to a double Warren truss structure (**Fig.4**). The butterfly web comprises precast panels fabricated off-site at a plant using high strength fiber reinforced concrete with specified design strength of 80 MPa and steel fibers are used to enhance shear capacity(**Fig.5**).

Inside the panels, prestressing steel members are placed to align with the orientation of tension acting on the panels. Prestressing is used as the method of pretensioning. The prestressing steel components are 15.2 mm diameter strands. There is no reinforcing steel, which makes the panels easy to work with and makes maintenance easy.

Based on the main girder height and the size of the indentations that make the butterfly shape, the butterfly web panels were designed to be 2.9 m long and were installed at a 3.0 m interval. As described above, in terms of resistance to shear force, the behavior of the butterfly web is similar to that of a double Warren truss. Consequently, shear force is broken down into compressive force and tensile force, which are transmitted separately. The area of tensile stress is reinforced by prestressing steel, with the amount of steel determined such that there is no tensile stress intensity under dead load, and such that no cracking occurs under design load

Web panel thickness is 150 mm, a thickness designed to be sufficient for the necessary amount of prestressing steel as described above, and to be able to resist the compressive force acting on the compression side under ultimate load.

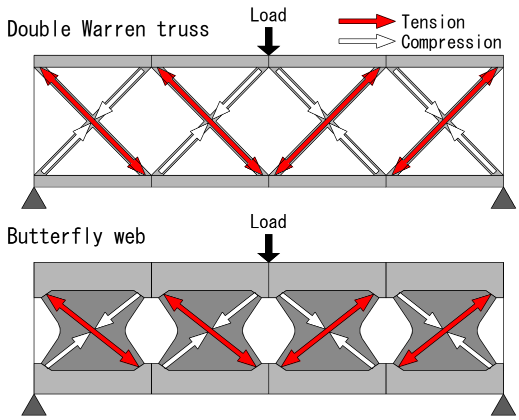


Fig.4 Structural behavior

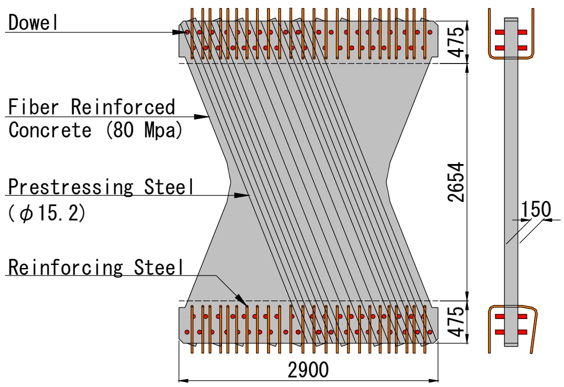
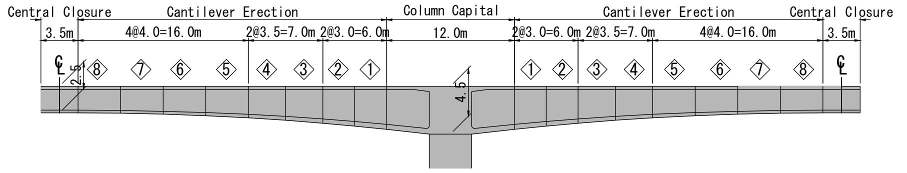
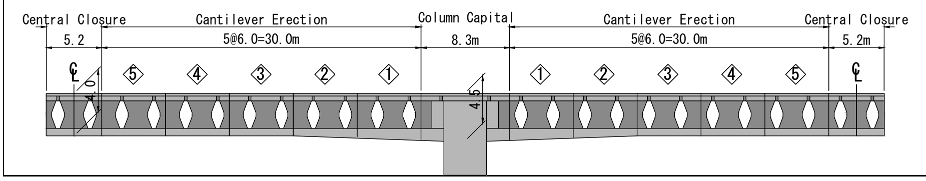


Fig.5 Butterfly web

Table 1 Comparison box girder and butterfly web

Side view & Section	Weigt (superstructure)	Prestressing steel	Block length
Box Girder (concrete web) 	153000kN (1.00)	287t (1.00)	3.0～4.0m 8blocks
Butterfry Web 	138800kN (0.91)	233t (0.81)	6.0m 5blocks

(2) Main girder

The butterfly web panels that comprise the web are discontinuous in the longitudinal direction of the bridge, and the panels are relatively thin. This results in the web being less rigid than that of an ordinary concrete web with a box section. Consequently, greater unit bending stress occurs in the web due to dead weight and vehicle loads. For this reason, transverse reinforcing ribs are installed at 3.0 m interval (**Fig.6**).

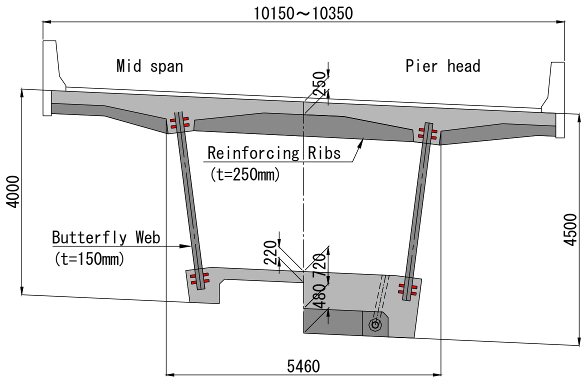


Fig.6 Main girder section

3. Construction of Takubogawa Bridge

(1) Butterfly web

The butterfly web panels are fabricated at a plant situated 270 km away from the bridge construction site, and transported to the site by truck. In total, the bridge requires 444 web panels, and although external shape and thickness are standardized. Since prestressing force is applied early at the fabrication stage, steam curing is used to accelerate strength gain. Prefabrication process of the panel is shown in **Fig.7**.

Fig.7 Prefabrication stage of the panel

(2) Cantilever construction

The cantilever construction used for the Takubogawa Bridge is shown in **Fig.8** and **Fig.9**. Each butterfly web panel weighs approximately 3.3 t, enabling construction of a main girder lighter than would be possible with a conventional concrete web. Consequently a construction block length of 6.0 m could be used, equivalent to the length of two butterfly web panels on each side of the bridge. As a result, the butterfly web enables construction with only five segments for a cantilever span, whereas conventional concrete box girder requires eight segments (**Table 1**). With fewer blocks required, the construction period can be substantially shortened. In addition, since the butterfly web panels are not continuous in the longitudinal direction, there is no need for work to join adjacent web elements, which also enhances execution efficiency. The butterfly web panels are lifted to the bridge deck by crane after transportation to the site, and then moved to the cantilevered deck ends where the form travelers are

Fig.8 Cantilever construction

located. Inside the form travelers, the panels are picked up and positioned as required, and then the concrete for the upper and lower deck slabs is placed to construct the main girder. **Fig.10** shows panels being put into position inside a form traveler. Central closure is shown in **Fig.11**.It is executed using a form traveler and then external cables are tensioned.

4. Conclusion

In addition to enabling a lighter main girder, the butterfly web structure makes a substantial contribution to faster construction times due to advantages such as requiring a smaller number of construction segment increments. Piers and footings can also be scaled down because of the lighter superstructure, and as a result, the bridge has a smaller impact on the environment than if it were to be constructed using a conventional structure. Furthermore, maintenance is easier as the web panels do not use reinforcing steel, and are high quality products produced in a plant using industrial fabrication processes. Consequently, this structure provides substantial reductions in both construction costs and maintenance costs.

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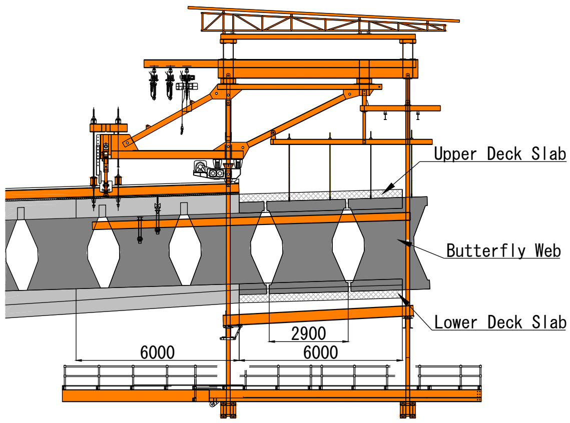

Fig.9 Form traveler

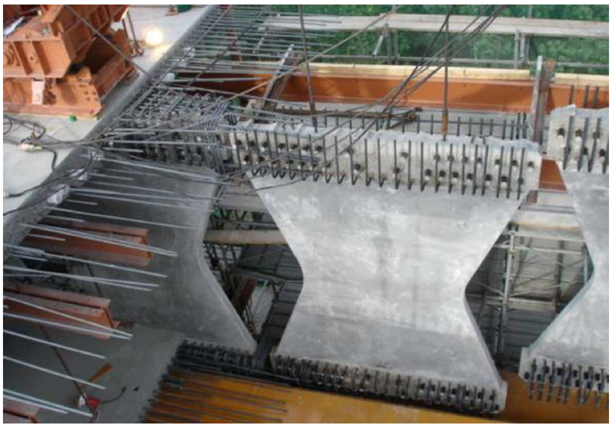

Fig.10 Panels inside a form traveler

Fig.11 Center closure

概　要

田久保川橋は，東九州自動車道の一部を構成している橋長712.5m の PC10径間連続箱桁橋である。本橋は，ウェブに蝶型形状のコンクリート製パネルである「バタフライウェブ」を初めて採用した新しい構造形式の橋梁である。バタフライウェブは，その構造特性としてせん断力が圧縮力と引張力に分解されて伝達される。そのため設計基準強度80Mpa の高強度繊維補強コンクリートをプレテンション方式で補強した工場製作のプレキャストパネルが用いられており，従来のコンクリートウェブ箱桁構造に比べて橋梁上部工重量を約10% 軽量化することが可能な構造である。

主桁には張出し施工が用いられており，ウェブの軽量化により 1 ブロックの重量が低減できたため，ブロック長をすべて6m に設定することが可能となった。これにより施工ブロック数が減少するため，当初計画に比べて工期短縮を可能とした。