4-Span PC Extradosed Bridge Intersecting the River at 30 Degrees
— Kyushu Shinkansen Onogawa Bridge —

河川と30度で交差する4 径間連続 PC エクストラドーズド橋
— 九州新幹線 大野川橋梁 —

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Keywords: extradosed bridge, landscape design, wind resistant stability

DOI: 10.11474/JPCI.NR.2014.129

Synopsis
Kyushu Shinkansen Onogawa Bridge is located in the northern section of the Kyushu Shinkansen Kagoshima Route, the high speed railway between Hakata station and Kagoshima-Chuo station. Because the bridge crosses the river at the angle of 30 degree and it is forbidden to layout pier in the bank for safety of the river, the spans in the river were set to 2@113 m. To reduce the stress in the girder at the central pier and to consider noise of train and landscape for the dense residential area, this bridge was planned as 4-span continuous PC extradosed bridge.

Structural Data
Structure: 4-span continuous PC extradosed bridge
Bridge Length: 286m
Span: 30m + 2@113m + 30m
Width: 12.4m
Owner: Japan Railway Construction, Transport and Technology Agency
Designer: Yachiyo Engineering Co., Ltd.
Contractor: Obayashi – Oriental Shiraishi – Mori JV
Location: Kumamoto Prefecture, Japan

1. Introduction
Kyushu Shinkansen Onogawa Bridge is located in the northern section of the Kyushu Shinkansen Kagoshima Route. The northern section, between Hakata Station and Yatsushiro Station, is the secondly opened section of the Kyushu Shinkansen Kagoshima Route, the high speed railway between Hakata station and Kagoshima-Chuo station. This bridge is 4-span continuous PC (presutressed concrete) extradosed bridge. The characteristic of the construction site is as follows;
- The bridge crosses the river at the angle of 30 degree.
- The river at the site is a tidal river, which can cause the salt attack.
- There is dense residential area in the right bank side of the river.

The outline of this bridge is shown in Fig.1.

2. Structural Design
(1) Design Requirement
River administrator required as follows;
- The length of span should be more than 23 m at the right angle to the direction of river flow (more than 50 m when cross angle is 30 degree).
- The ratio of total pier width for the width of river should be less than 8 %.
- The height of clearance under the bridge should be more than 4.5 m.

(2) Structural Planning
Because it is forbidden to layout pier in the bank for safety of the river, the spans in the river were set to 2@113 m. In addition, it is necessary to consider noise of train and landscape for the dense residential area. Generally, special measurement against noise
is required for steel bridge. Therefore PC extradosed bridge was planned because of economy, noise reduction and landscape.

As a result of study of 2-span continuous girder (113 m + 113 m), the stress in the girder at the central pier exceeded the limit. Finally, this bridge was planned as 4-span continuous PC extradosed bridge (30 m + 113 m + 113 m + 30 m) by integrating both side span girders to reduce the stress.

(3) Structural Characteristics
The characteristic of Onogawa Bridge is as follows.

1) The Shape of Central Pier
The shape of P3 pier cross-section is an oval, the long side of which is directed to the river flow direction. Because main girder and long side of the pier crosses at 30 degree, a corbel was adopted to the structure for the articulation of the girder and the pier. The shape of the corbel is made curved considering aesthetics (Fig.2).

2) Measure for Negative Reaction
Because the lengths of the side spans are much shorter than the main spans, it is required to consider negative reaction under live load. Counterweight concrete was added on the lower side of the cross girders (440 kN) (Fig.3 a) and inside of the box girder of the side spans (3,660 kN) (Fig.3 b) to prevent negative reaction.

3) Measure for Salt Attack
The thickness of cover concrete is more than 100 mm as a measure for salt attack by tidal river.

3. Pylon and Stay Cable
(1) Pylon
The pylon continuously varies shape to the corbel and perpendicularly crosses the girder. The prefabricated saddles (Fig.4) of stay cables are placed in the pylon.

Fig.1 Overview of the bridge (unit: mm)

Fig.2 The shape of central pier

The saddle is consist of steel tubes within polyethylene pipes. The saddles enable the replacement of stay cables. The small amount of reinforcement around saddle contribute to improve the aesthetics and weight reduction to allow slim shape.

(2) Stay Cable
1) Design
Because this bridge crosses tidal river, stay cable
anchors are placed in the box girder as a measure against salt damage. The stay cable strand is protected by triple layers, i.e. epoxy coating, cement grout and polyethylene (PE) pipes. The PE pipes with inner ribs were adopted to follow thermal expansion of strand and grout. Because deflection of stayed deck, caused by excessive thermal expansion of stay cable, make it difficult to keep truck level suitable for high speed train[1], thermal insulation of the cable is planned. The grout was planned to be thicker than usual, with φ200 mm PE pipe. The light color paint was applied to the stay surface to prevent heating. The cross-section of the stay cable is shown in Fig.5.

The color of the stay is light orange, which stand for “Hinokuni” (former name of Kumamoto Pref. meaning land of fire), “Dekopon” (citrus fruit widely cultivated in Kumamoto Pref.) and “Shiranui” (meaning unknown fire, mysterious luminescence phenomenon in the sea near this bridge).

2) Wind Resistant Stability

Wind resistant stability of stay cable was examined on rain vibration. The stay cable with natural frequency of less than 3 Hz and Scruton number (Sc) of less than 60 are capable of being excessively vibrated by wind of velocity 6 m/s in rain. Dampers (logarithmic decrement $\delta$ = about 0.03) are generally installed to each cable as measure against rain vibration[2][3].

Because 48 of 64 stay cables of this bridge have less natural frequency than 3 Hz and all have Sc 19.4 in analysis, dampers were planned for all the cables in consideration of uncertainty.

Although logarithmic decrement $\delta$ of stay cable is one of the significant parameter to examine Sc, the value of $\delta$ (0.005) was only assumed by experiences of bridges constructed in the past. Therefore, to confirm natural frequency and logarithmic decrement of cables, vibration test (Fig.6) was carried out. The result indicated that natural frequencies (1.5 - 4.4 s) and logarithmic decrement $\delta$ (0.004 - 0.016) of stay cables were same level as expectation. The value of Sc was estimated at 16.3 without dampers. The value of Sc of all the cables was estimated more than 100 after the damper installation.

4. Erection of Girder

The main spans were erected by balanced cantilever method, whereas the side spans were erected with conventional falseworks. The side spans acted as the counter weight for cantilever erection. The construction procedures are shown in Fig.7.

5. Conclusion

As a result of overcoming severe conditions, this bridge was planned as 4-span continuous PC extradosed...
bridge. It is quite unusual to adopt PC extradosed bridge for Shinkansen in Japan. Therefore this bridge will be a landmark of Kyushu Shinkansen and Uki City, Kumamoto Prefecture.

The northern section of the Kyushu Shinkansen Kagoshima Route including this bridge started operation in spring of 2011.

References