Design and Construction of Extradosed Bridge of Hokuriku Shinkansen Adjacent to an Existing Railway Bridge
— Jinzu River Bridge —

既存鉄道橋に隣接する新幹線橋梁（エクストラドーズド橋）
— 北陸新幹線　神通川橋りょう —

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Synopsis
The Jinzu River Bridge is a railway bridge for the Hokuriku Shinkansen bullet train line between Takasaki and Kanazawa. The bridge crosses over the Jinzu River and is located in Toyama Prefecture, Japan (**Fig.1**). It is an extradosed bridge that is intermediate structural system between a box-girder bridge and a cable-stayed bridge. The total length of the bridge is 428m with a 128m maximum span, which was the second-longest span as an extradosed railway bridge in Japan as of its completion. The bridge went into service with the opening of Hokuriku Shinkansen in March 2015.

Fig.1 Jinzu River Bridge

Structural Data
Structure: 4-span continuous extradosed bridge
Bridge Length: 428m
Span: 85m + 128m + 128m + 85m
Width: 13.7m
Tower Height: 15.0m
Box-girder Height: 3.5–6.0m
Design Speed: 180km/h
Curve Radius: Straight line
Track Type: Slab track
Bridge Foundation: Bored pile / Pneumatic caisson
Bearing Apparatus: Sliding bearing + Rigid stopper / Sliding bearing + Damper stopper / Rubber bearing + Damper stopper
Construction Period: Oct. 2011 – Oct. 2015
Location: Toyama Prefecture, Japan

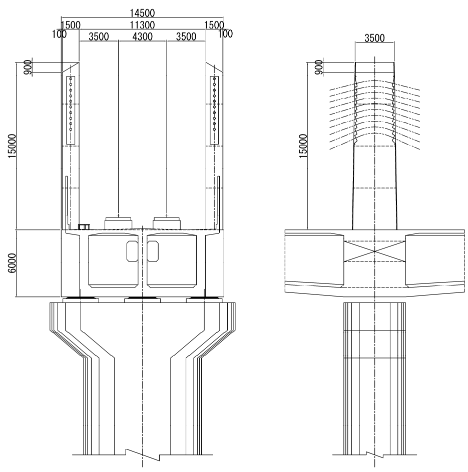

Fig.2 Typical cross section

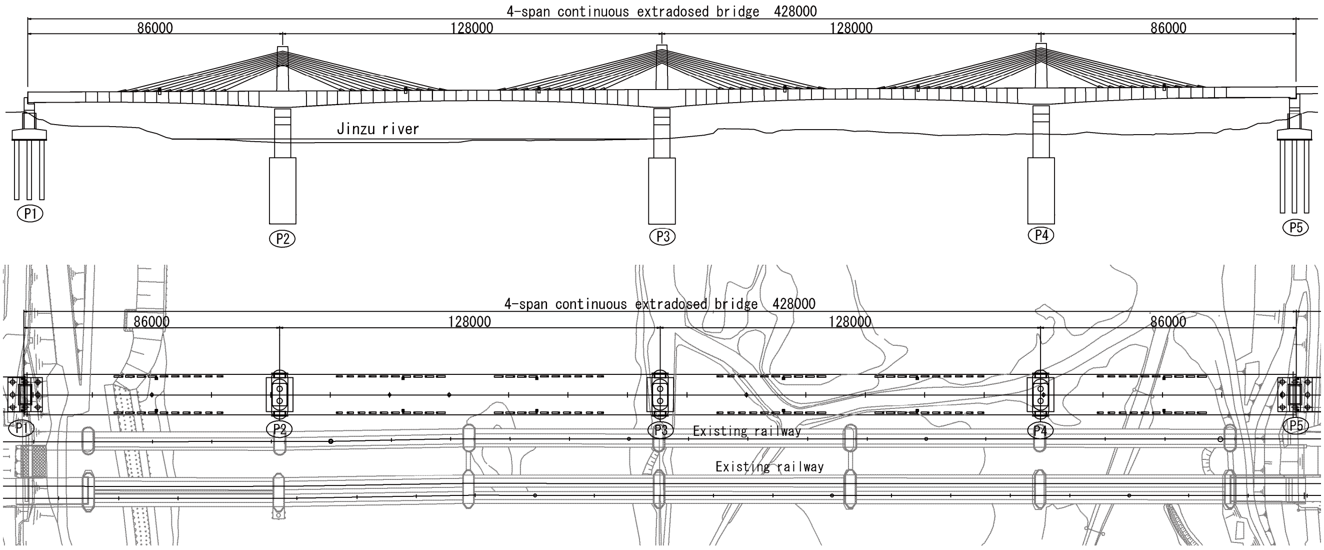

Fig.3 General view

1. Introduction

The Jinzu River Bridge is a 4-span continuous extradosed bridge with a 128-m-long main span. This is the second-longest span as an extradosed railway bridge in Japan.

The bridge was constructed within several constraints, such as on the construction period and method, because the construction took place in the river and adjacent to an existing railway bridge. Hereinafter, a summary of the project is given.

2. Design

(1) Structural Type

To choose the structural type, a comparison was made on the condition that the structure should satisfy restrictions on construction in the river and adjacent to an existing railway bridge. A 4-span continuous extradosed bridge was selected as a result, for the following reasons:

- Minimum temporary diversion of the river
- Advantages in structure, maintenance and aesthetics
- Satisfactory performance as a bridge for the Shinkansen

(2) Design of Superstructure

Because the bridge is a cable supported structure with a 128-m-long main span, expansion/contraction and up/down displacement of girders due to temperature changes were concerns. The key requirements as a high-speed railway bridge are safety tracking and comfortable serviceability for passengers. Accordingly, a bearing system was adopted for all supporting points as follows and stoppers were arranged against horizontal forces:

- Rubber bearing at pier 3
  (support condition: fixed)
- Sliding rubber bearing at piers 1, 2, 4, and 5
  (support condition: movable)

The anchoring positions of the stay cables, the shape of the soundproof walls and the arrangement of the snow-melting panels were considered when the detailed structural type of the superstructure was selected. As a result, an extradosed bridge with double-plane stay cables having twin-cell box girders (**Fig.2**) was selected.

Regarding the allotted shearing-force ratio of the outer web to the inner web, which was a problem that arose in the aforementioned selection, three-dimensional finite-element method (FEM) analysis was undertaken for the decision.

(3) Design of Bridge Foundation in the River

Three bridge-foundation plans—a pneumatic caisson foundation, a steel-pipe sheet-pile foundation, and a well foundation—were examined based on design conditions such as workability and the impacts on the existing adjacent railway bridge, ground water, and the river. After evaluation, the pneumatic caisson foundation was selected for the pier foundation in the river because it had the least impact on the existing adjacent railway bridge.

3. Construction of Substructure

(1) Outline

The substructure construction period was limited to the flood-free season of the Jinzu River, *i.e.* from October through June. To ensure the required water flow section of the river, the waterway was diverted according to the circumstances.

(2) Neighboring Construction

Because the existing adjacent railway bridge was built about a hundred years ago, its condition was examined and verified. The displacement limit of the existing bridge was defined as 7mm (both horizontally and vertically) and the actual displacement was closely monitored and measured during bridge construction.

In addition, a vibration isolation wall (steel sheet pile) was installed in front of the existing bridge. Its embedment depth was designed based on the

displacement estimated by FEM analysis.
The actual maximum displacement was 4mm during the construction period, and construction was completed without affecting the train service on the adjacent railway bridge.

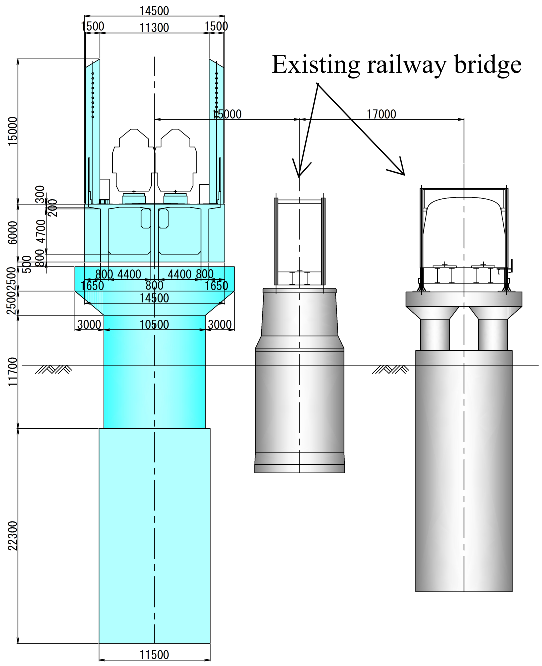

Fig.4 Positional relationship

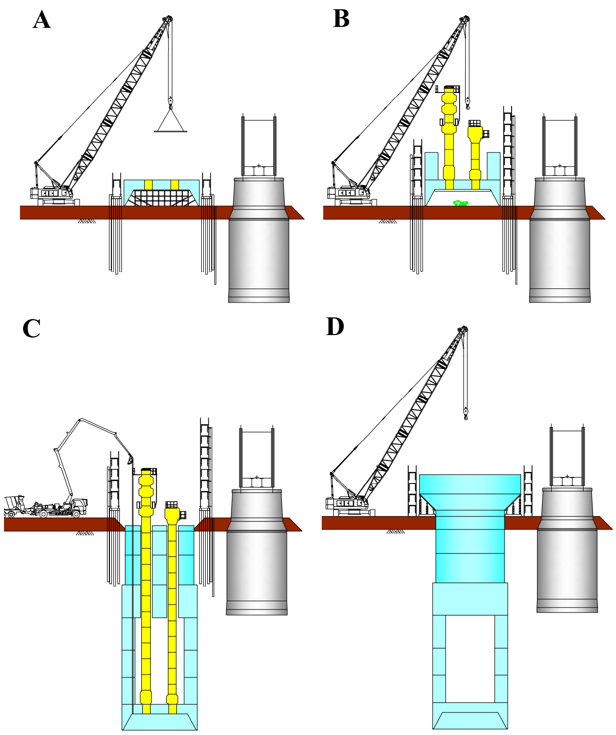

Fig.5 Construction sequence of pneumatic caisson

A: Construction of platform and setting of cutting edge
B: Caisson assembly and excavation
C: Concrete casting after completion of settlement
D: Construction of beam

(3) Pneumatic Caisson

The excavation for the pneumatic caisson was carried out by manned and unmanned excavation depending on the pressure in caisson. From the viewpoint of safety and efficiency in a high-pressure work area, a ground-running-type backhoe (manned excavation) was used when the pressure in the caisson was less than 0.18MPa, and overhead-traveling-type backhoe (unmanned excavation) was used for pressures over 0.18MPa.
An immersion control system with automatic measurement was adopted for measuring settlement. Chronological changes in settlement and inclination of the caisson were monitored in real time. As a result, highly accurate construction management (settlement measurement accuracy: ±1.5mm, inclination measurement accuracy: 0.035°) was achieved. The construction sequence of the pneumatic caisson is shown in **Fig.5**.

4. Construction of Superstructure

(1) Outline

The pier head and side span were constructed using scaffolding assembled from the ground, and the main girder was constructed by a cantilever construction from each pier. The box girder has 14 in-situ segments with 3.5–4.0-m-long blocks for cantilever construction. The tower was constructed by falsework on the deck after construction of the pier head. The construction sequence of the superstructure is shown in **Fig. 6**.

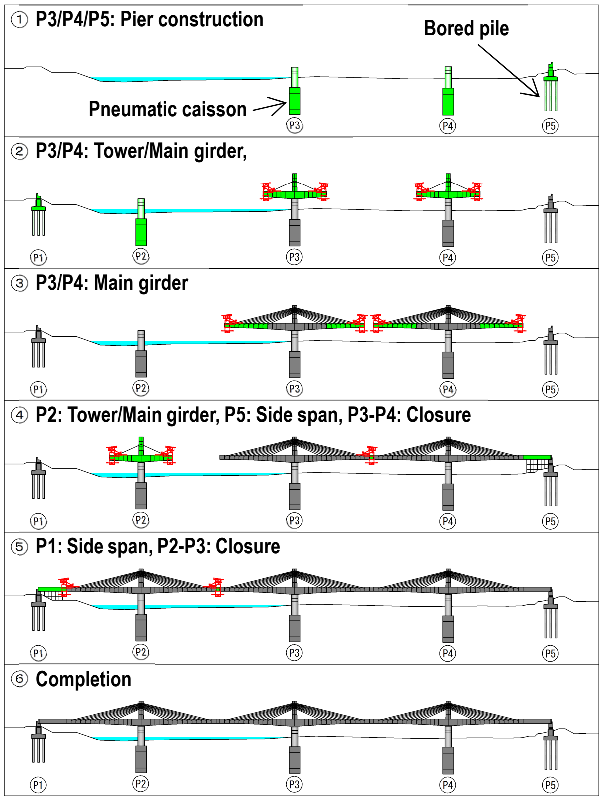

Fig.6 Construction sequence of superstructure

(2) Construction of Pier Head

The length of the pier head is 16m, the girder depth is 6m, and the diaphragm width is 5.5m. To control cracking of the mass concrete, the concrete crack index was estimated by temperature stress analysis, and heat-insulating forms using Styrofoam-treated plywood were adopted to reduce the temperature difference between the concrete interior and exterior.

(3) Construction of Main Girder

The main girder was constructed by the cantilever costruction using a form traveler.

Fig.7 Main-girder construction by cantilever system

The construction was carried out in a cold region where the average daily ambient temperature from December to March was less than 5°C. The countermeasures for cold-weather concrete under 5°C was taken. The curing temperature was kept above 10°C for three days after concrete casting, whereupon the concrete temperature was kept above 0°C for another two days.

(4) Tower Construction

Self-compaction concrete was used for congested reinforcement. The tower has two-layer 51-mm-diameter reinforcement with close spacing; it required self-compaction concrete to prevent defect concrete. **Table-1** gives the design mix of the self-compaction concrete. Limestone fine powder was used to control excessive heat of hydration while maintaining workability and to prevent cracking.

Table-1 Design mix of high-workability concrete

Strength	30 N/mm^2
Slump	700±50 mm
Air content	5.5±1.5%
Water–cement ratio	53.9%
Cement	310 kg/m^3
Limestone fine powder	266 kg/m^3
Water	167 kg/m^3
Thickening agent	0.3 kg/m^3

(5) Stay Cables

The stay cables have a triple rust-preventive structure as shown in **Fig.8**.

For high-speed railway bridges, track displacement is severely restricted for travel safety and ride comfort. Therefore, the stay cable High-Density Polyethylene (PDHE) sheath with an outer diameter of 200mm was employed instead the usual 140mm diameter PDHE sheath to reduce the deflection of the main girder and fluctuation of stay cable forces due to temperature changes.

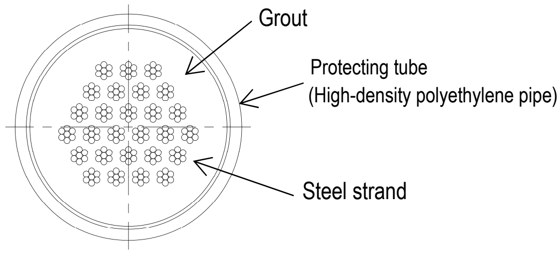

Fig.8 Cross section of stay cable

5. Conclusion

The Jinzu River Bridge is a 4-span continuous extradosed bridge with a 128-m-long main span. This was the second-longest span as an extradosed railway bridge in Japan as of its completion. The bridge was built within several constraints, such as on the construction period and method, because of construction in the river and adjacent to an existing hundred-year-old railway bridge. The bridge was completed successfully thanks to careful prior examination and highly accurate construction.

概　要

北陸新幹線神通川橋りょうは，富山県に位置し，一級河川神通川を JR 高山本線・北陸本線と並行して渡河する橋長428m の 4 径間連続 PC エクストラドーズド橋である。最大支間長128m は，鉄道橋における PC エクストラドーズド橋としては国内第 2 位であった。

上部工の構造形式は 2 室箱桁断面を有する二面吊のエクストラドーズド橋であり，列車の走行安全性および乗り心地の観点から全支点に支承構造を採用した。河川内橋脚（P2～ P4）の基礎は，近接する既設橋りょうへの影響が少ない矩形のニューマチックケーソン基礎を採用した。

近接する JR 高山本線の既設橋脚が築約100年と非常に古いため，事前調査から変位量の限界値を定め，変位計測を行いながら施工を進めた。上部工の施工は，柱頭部構築後，P3，P4 の張出し架設を同時に行い，張出し施工の進捗に合わせ主塔の構築および斜材の緊張作業を行った。