Design and construction of double-decked prestressed concrete bridge

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Objekttyp: **Article**

Zeitschrift: **IABSE reports = Rapports AIPC = IVBH Berichte**

Band (Jahr): **55 (1987)**

PDF erstellt am: **29.04.2024**

Persistenter Link: https://doi.org/10.5169/seals-42738

Design and Construction of Double-Decked Prestressed Concrete Bridge

Conception et construction d'un pont mixte à deux étages en béton précontraint

Planung und Ausführung einer Spannbetonbrücke mit zwei Fahrebenen

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SUMMARY
On the Island of Yoshima, as a part of the Honshu-Shikoku Bridge Project, a viaduct with tall piers was built using prestressed concrete girders in consideration of maintenance, noise and vibration. A multi-span continuous structure was adopted in view of a reduction in the number of expansion joints and resistance to earthquakes.

RÉSUMÉ
Sur l'île de Yoshima, desservie par les ponts Honshu-Shikoku, un viaduc à piles surélevées a été construit en béton précontraint en tenant compte de la maintenance, du bruit et des vibrations. La superstructure de ce viaduc est constituée d'une poutre continue sur plusieurs travées afin de réduire le nombre de joints de dilatation et d'améliorer la résistance aux séismes.

ZUSAMMENFASSUNG
Auf der Insel von Yoshima wurde, im Rahmen des Brückenprojekts Honshu-Shikoku, ein Viadukt auf hohen Pfeilern erstellt, unter besonderer Berücksichtigung von Unterhaltung, Lärm und dynamischer Einwirkungen. Den Ueberbau bildet eine durchlaufende Spannbetonkonstruktion, um die Anzahl von Dilatationsfugen zu verringern und den Widerstand gegen Erdbeben zu verbessern.

1. INTRODUCTION

The Yoshima Viaduct has been constructed on the Island of Yoshima as part of the Kojima-Sakaide route of the Honshu-Shikoku Bridge Project. The Viaduct is a 717 m long prestressed concrete bridge with high piers, adjacent to a suspension bridge to be built over the international navigation as shown in Figs. 1 and 2.

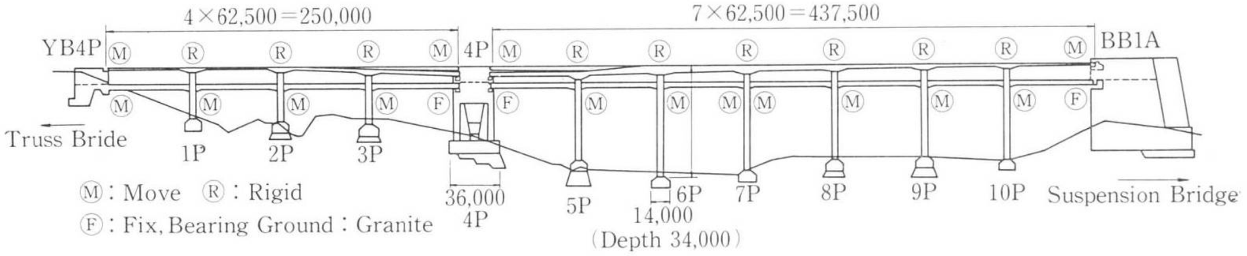

Fig. 1 General View of Yoshima Viaduct

This viaduct has the following features:

(1) It uses prestressed concrete girders for the highway (upper) and railroad (lower) decks.

(2) It is a three-dimensional frame in which the upper deck is rigidly connected to the horizontal beam of each pier.

(3) The piers are very high (max. height: 79 m) and slender (max. depth: 4 m).

(4) The piers are mixed structures in which a steel frame is encased in reinforced concrete.

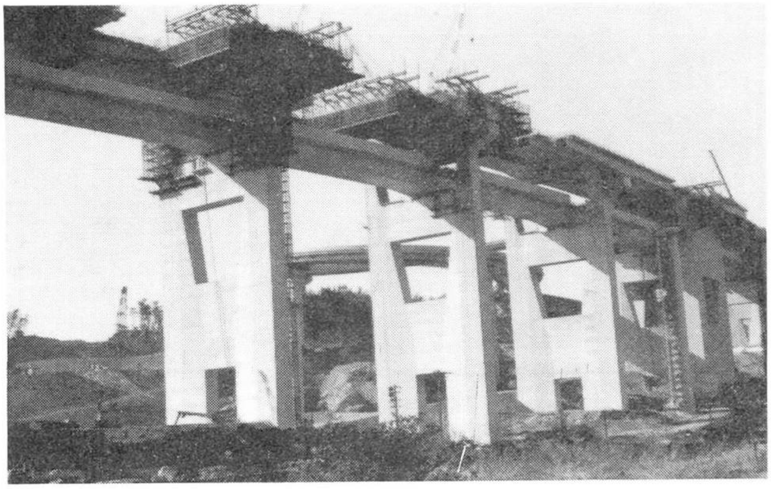

Fig. 2 Construction of Yoshima Viaduct

At present, the prestressed concrete girders for the highway deck are under constructin for scheduled completion in the spring of 1988.

2. PLANNING OF THE BRIDGE

A prestressed concrete structure was selected as the superstructure in consideration of maintenance, noise and vibration. A multi-span frame structure was employed for better traffic running characteristics and seismicity. As a result, the total weight of the superstructure is very heavy, and the influence on the substructure during an earthquake is dominant. Therefore, the selection of a structural type that excels in seismicity became a major factor in the bridge planning.

The railroad girders are fixed at the massive substructure, and are movable at the other supports to reduce the horizontal force on the high piers during an earthquake (see Fig. 1). Stoppers are introduced at the movable supports to prevent the girders falling from the bridge.

As the highway girders are heavier than the railroad girders because of their greater width, it is difficult to employ the concentrately fixed support method used for the lower deck. Therefore, a multi-rigid frame method, that reduces the restraints on the rigid piers, was employed by considering the viaduct as a higher pier bridge.

3. DESIGN OF THE VIADUCT

Fig. 3 shows a general view of a pier. The highway deck is designed to accommodate 4 lanes of traffic (22.5 m in width). Two conventional railroad lines will be constructed on the railroad deck, and provision is made for the future addition of double Shinkansen tracks.

3.1 Design of the Pier

A spread foundation was adopted for this viaduct, because of the existence of granite under a thin layer of soil. As the piers are very tall and slender, the earthquake resistant design was performed by both ordinary methods and a dynamic analysis (spectrum response analysis).

The seismic coefficient in the direction at right angles to the bridge axis is K = 0.19, and in the axial direction is K = 0.17 for 1p - 3P, and K = 0.08 for 5P - 10P (natural period: 2.6 sec).

A long-period system structure that minimizes the pier thickness to the extent possible was needed in the bridge axial direction, and a highly rigid structure in the direction at right angles to the bridge axis was required in view of the running characteristics of trains. Thus two or three layer rigid-frame piers were adopted.

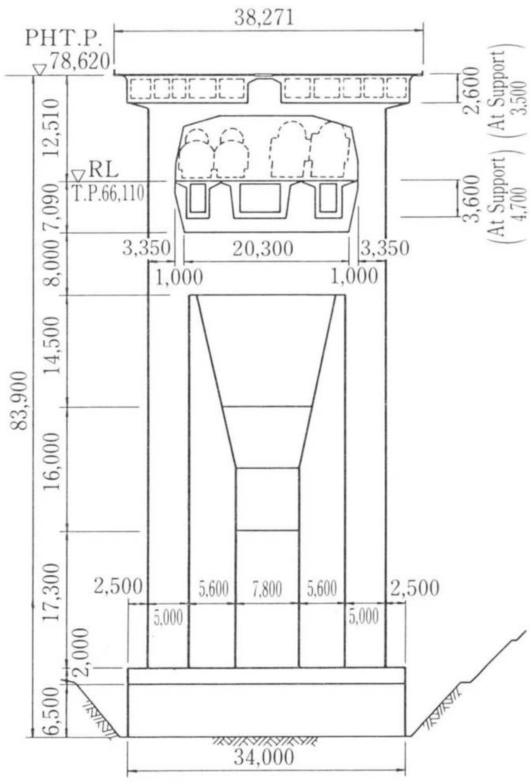

Fig. 3 General View of Pier (7P)

A mixed structure in which a steel frame is encased in reinforced concrete was adopted as the cross-sectional structure of the pier in consideration of its resistance to earthquakes and ease of construction (see Figs. 4, 5, 6).

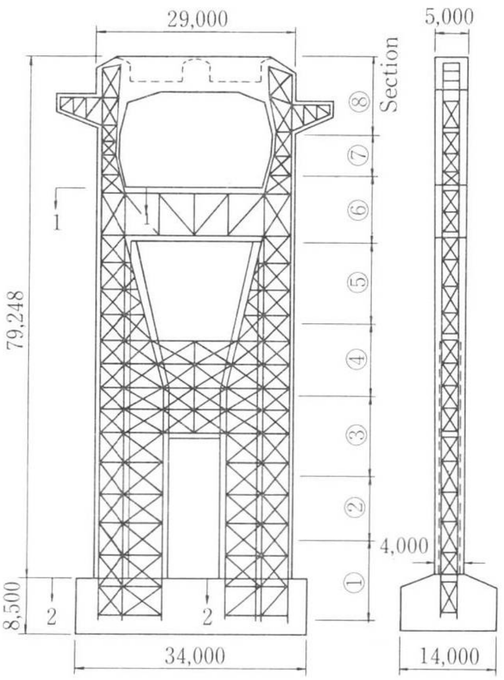

Fig. 4 Steel Frame (6P)

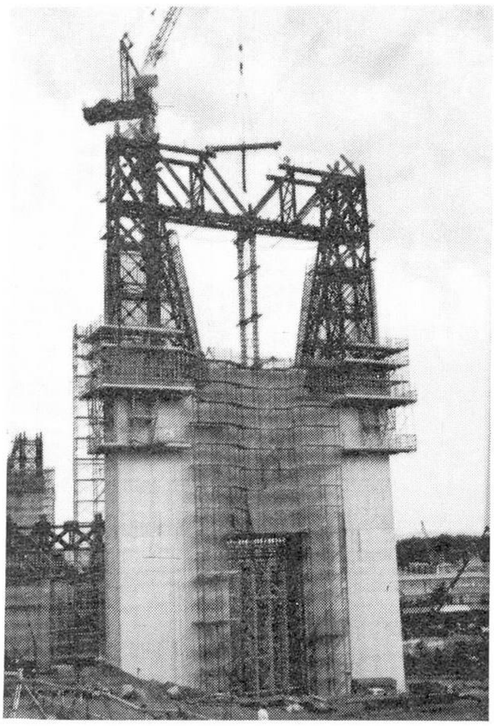

Fig. 5 Construction of Pier

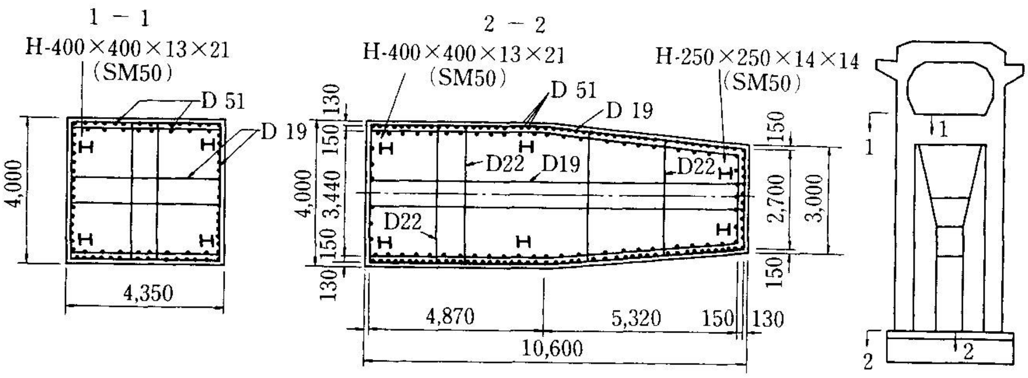

Fig. 6 Cross Section of Pier (6P)

The piers were designed by the same procedure as for ordinary reinforced concrete structures, and the relatively short span members, such as the intermediate beam and railroad supporting beam, were designed as deep beams. Stud connectors were buried directly in the steel frame anchor section to assimilate with the anchoring method of reinforcing bars in the outer part. Fig. 7 shows details of the steel frame embedded in the footing. To secure the concreting work, a steel frame with a large cross section was used and a closed structure was adopted to increase the ductility of the piers. H-section steel was used to construct the main frame (max. 458 x 417 x 30 x 50), and channel steel and angle steel were used as brace members.

At the pier base, the steel to concrete ratio is 1.1 to 1.4%, and the steel frame ratio to total steel is roughly 20%. In consideration of the durability of the structure, a depth of covering over reinforcing bars of 10 cm was adopted.

A 1/10 scale model test was made to find the ductility of the piers in both directions (see Figs. 8, 9 and 10).

Fig. 8 shows the representative Load-Deflection curves. It was confirmed that the safety level of the piers during an earthquake is very high and that a mixed structure has greater ductility than a reinforced concrete structure.

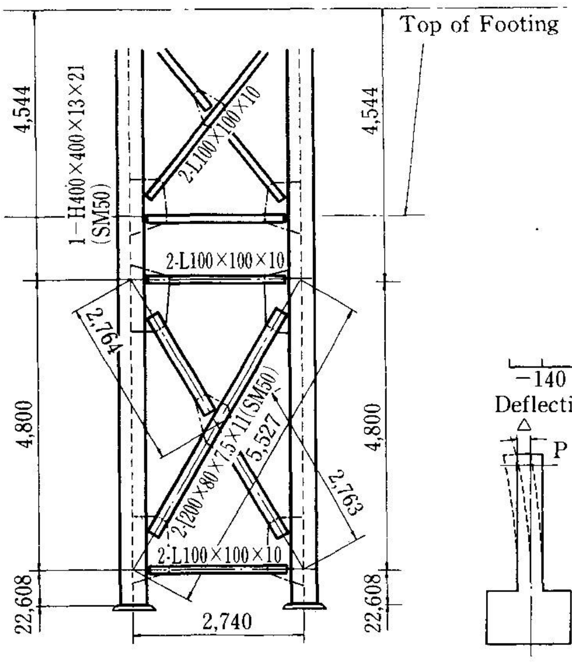

Fig. 7 Steel Frame Anchorage

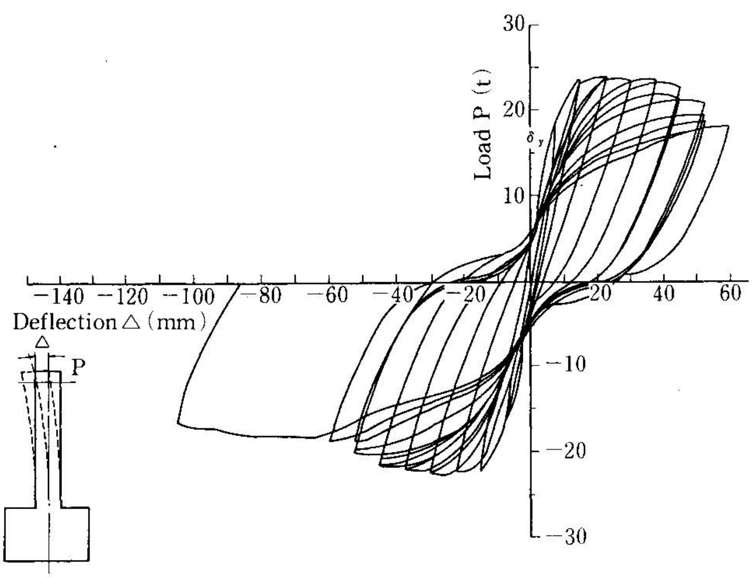

Fig. 8 1/10 Model Test of Mixed Structure in Bridge Axial Direction

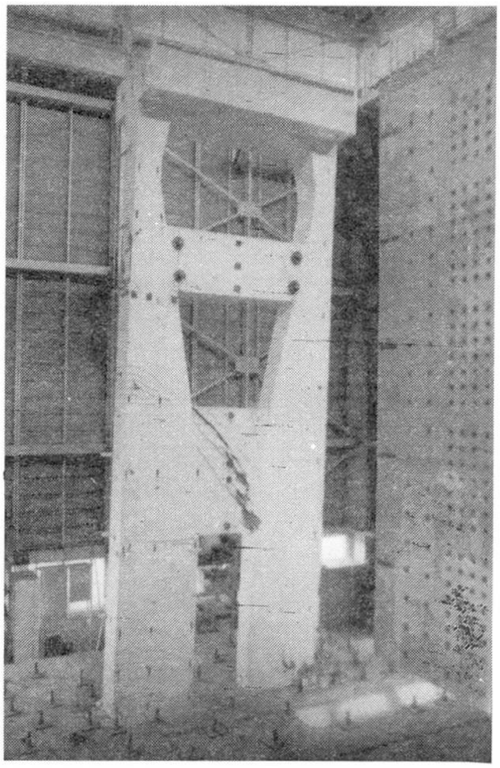

Fig. 9 1/10 Model Test in Direction at Right Angles to Bridge Axis

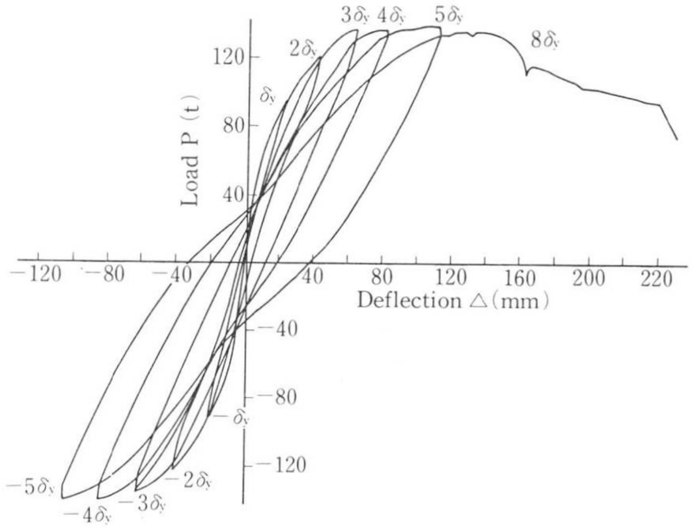

Fig. 10 Relation of Load-Horizontal Deflection at Upper Beam

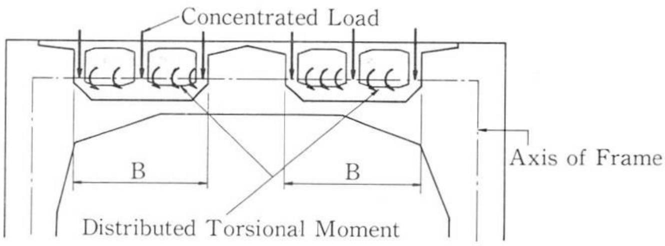

Fig. 11 Loading Condition at Pier

3.2 Superstructure Design

The highway girder of this viaduct is a solid rigid frame structure connected rigidly to the horizontal beam of each pier. As the highway girder axis line does not coincide with the pier post axial line because of restrictions imposed by construction limits of the railway section below, combined flexure, shear and torsional stresses are applied by both dead loads and seismic loads (see Fig. 11).

Thus, the following design methods were applied by utilizing the result of a basic experiment on torsion with respect to a short torsional span, and a 1/10 model test of this structure.

(1) A prestressed concrete structure was adopted for the upper horizontal beam on the assumption that it will suppress the development of cracks under the design load conditions, including an earthquake.

(2) Under ultimate load conditions, it is designed as a reinforced concrete member, disregarding the influence of prestressing.

(3) For the rigid-frame corners, a two dimensional analysis by finite element method was made and reinforcing bars provided to cope with the tensile force generted.

The prestressed concrete box girders for the highway and railroad decks have been erected by the cantilever erection method. Thus, those were designed by the same procedure as for ordinary prestressed concrete box girder bridges. The depth of cover over the reinforcement was increased to 5 cm for the outer faces of the box section (cover of the inner part of box: 3 cm).

In order to enable inspection and repair under the main girders and floorbeams whenever necessary, anchor bolts were inserted in advance into the girder so that an inspection car and suspended scaffolding may be supported (see Fig. 12).

4. CONSTRUCTION

As the piers of the viaduct are very tall and their width in the bridge axial direction is small, a high level of accuracy is required. Therefore the steel frames were fabricated in the same manner as for a truss bridge and provisional assembly was also made.

The most important of all accuracies in steel frame erection is that of perpendicularity, and the inclination of each member and the structure as a whole was controlled below H/1000 or H/2500 + 10 mm. The control of the height in the first section was extremely important as it forms the base for the steel frame erection.

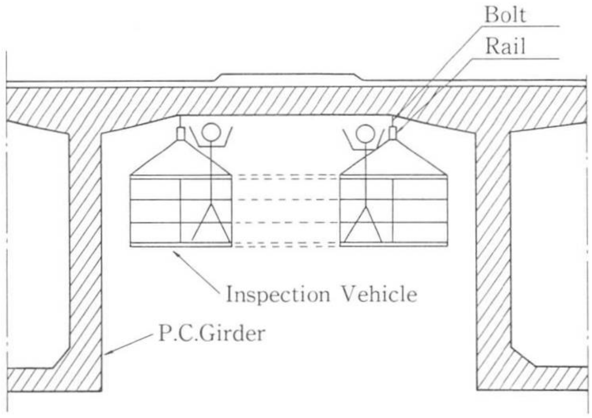

Fig. 12 Inspection System of P.C. Girder

Reinforcing bars were assembled by utilizing the steel frame as a ruler (see Fig. 13). The standard concrete lifts for the footings, columns and beams are 1 m, 3 m and 2 m, respectively. In summer, cooling water of roughly 5°C was used as mixing water to lower the concrete temperature for placing.

The average compressive strengths of the footings and piers was 38 and 41 MPA, respectively.

On completion of the substructures, the railroad girders in the lower deck were erected by the cantilever erection method. The highway girder in the upper deck then erected, also by the cantilever erection method. During the construction of the highway girder, the railroad girder was fixed temporarily for structural stability, as shown in Fig. 14. Average compressive strength of the prestressed concrete girders was 49 MPA.

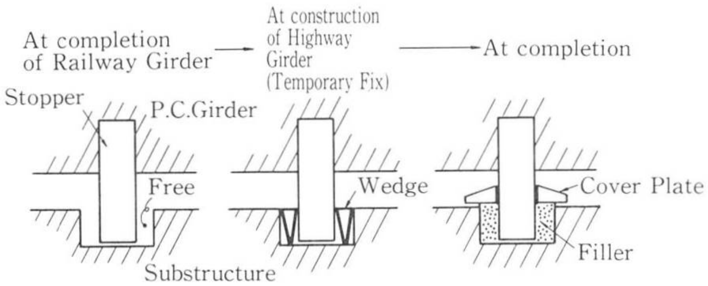

Fig. 14 Railroad Girder Stoppers at Piers

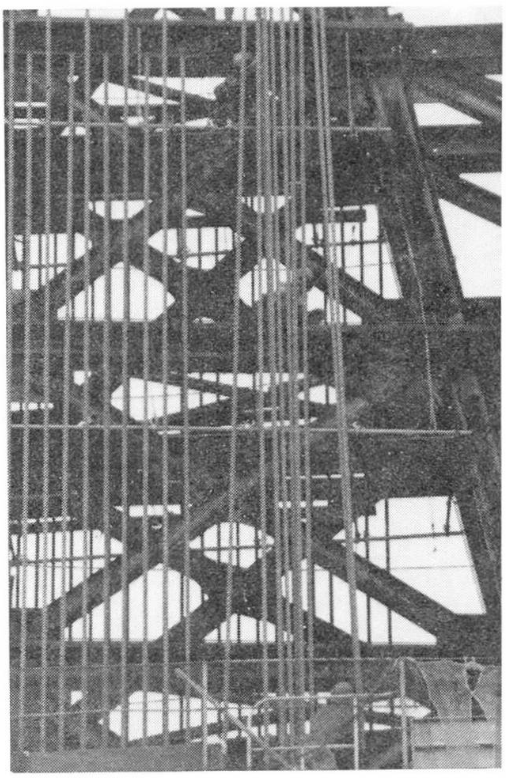

Fig. 13 Assembly of Reinforcing Bar

5. CONCLUSION

Several considerations for maintenance were made in the design of the viaduct on Island of Yoshima. After completion of the structure regular inspections will be made to maintain its condition.