Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

Band: 13 (1988)

Artikel: Design of long span prestressed concrete railway bridge

Autor: Yoshida, Iwao / Jin, Hiroo / Matsuda, Dairoku

DOI: https://doi.org/10.5169/seals-13092

Design of Long Span Prestressed Concrete Railway Bridge

Conception d'un pont de grande portée en béton précontraint pour voie ferrée

Auslegung einer Spannbeton-Eisenbahnbrücke großer Spannweite

Iwao YOSHIDA
Director
Honshu-Shikoku Bridge Auth.
Tokyo, Japan

Born in 1925, obtained his engineering degree and doctorate at University of Tokyo.

Dairoku MATSUDA
Manager
Sakaide
Construction Office
Kagawa, Japan

Born in 1946, graduated from Central Railway Training School, Tokyo Japan.

Hiroo JIN
Chief of Research Div.
Honshu-Shikoku Bridge Auth.
Tokyo, Japan

Born in 1942, obtained his engineering degree at Kyushu University.

Masayuki OTSUBO
Deputy Manager
Kojima Construction Office
Okayama, Japan

Born in 1949, graduated from Central Railway Training School, Tokyo, Japan.

SUMMARY
This report summarizes the design of a five-span continuous PC box girder bridge having a span length of 120 m, the longest in Japan serving as a railway bridge. The safety of the structure and the reliable running of trains were examined using seismic response analysis. PC steel bars were used to resist for dead load of cantilever-erected girder and PC steel stranded wires were used for the completion system of train load. Low friction sheaths were used for the PC steel stranded wires.

RÉSUMÉ
Le rapport présente la conception d'un pont en poutre-caisson en béton précontraint à cinq travées continues d'une portée de 120 m, le plus long pont en béton précontraint pour voie ferrée du Japon. La conception est caractérisée par l'étude de la sécurité de l'ouvrage et la stabilité de roulement du train au moyen d'une analyse de réponse séismique, l'adoption des barres de précontrainte pour supporter le poids propre de la poutre en console, l'utilisation du toron de précontrainte pour le système de charge due au train, l'utilisation de la gaine à faible friction pour le toron de précontrainte.

ZUSAMMENFASSUNG
Dieser Bericht faßt die Auslegung einer fünffeldrigen Durchlauf-Hohlkastenträgerbrücke aus Spannbeton zusammen, die mit einer Spannweite von 120 m die längste Eisenbahnbrücke Japans ihrer Art ist. Die Auslegung ist dadurch gekennzeichnet, daß 1. eine seismologische Reaktionsanalyse der Bausicherheit und der Befahrbarkeit des Bahntrasses durchgeführt wurde, daß 2. für die Eigenlast des Freiträgers Spannbetonbalken mit Stabverspannung verwendet wurden und für die Fertigstellung des Geleisstreckevorbaus für die Spannbetonstruktur Kabel verwendet wurden, sowie daß 3. für die Hüllrohre reibungsarme Ausführungen verwendet wurden.

1. PREFACE

Kitaura-ko Bridge is located on the Shikoku side of the Honshu-Shikoku Bridge (for combined highway and railway use) connecting Honshu with Shikoku and is a railway bridge that spans over Kitaura fishing port.

The superstructure consists of a five-span continuous box girder having a span length of 120 m, the longest in Japan (refer to Fig-1).

The substructure consists of a cast-in-site diaphragms wall foundation that was adopted for the first time in Japan as a foundation for a marine structure (Fig-2).

This report describes the points of consideration in improving the aseismicity, economy and constructability of long bridges in the design of this bridge.

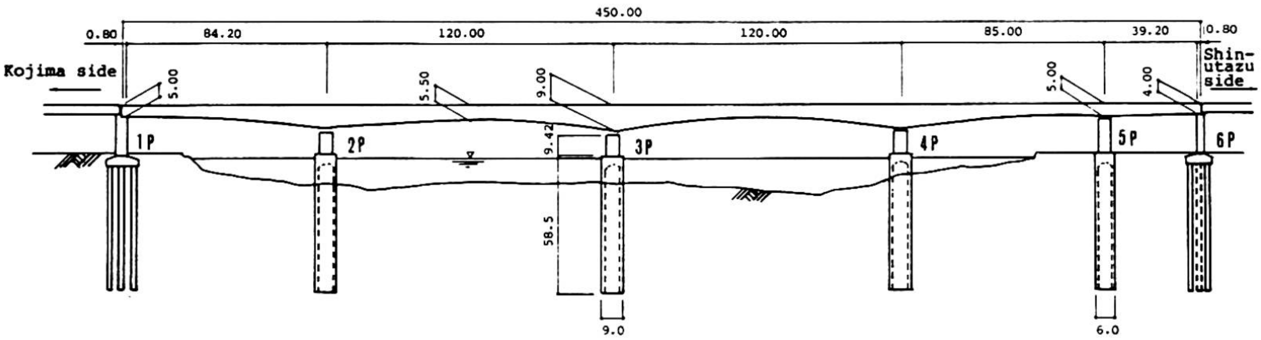

Fig-1 General drawing of the entire Kitaura-ko Bridge (m)

2. SEISMIC RESPONSE ANALYSIS

2.1 Analysis model

Recorded acceleration wave at the Kaihoku Bridge was used as a seismic wave and 4 cases were examined, i.e. longitudinal direction and transverse direction for both when completed and during construction. The input acceleration at the foundation bed (TP-91 m) was obtained using the multiple reflection theory so as to become 200 Gal. (100 Gal. during construction) at the aseismatic ground surface. As a result, the input acceleration at the foundation bed was measured to be 94 Gal.

The analysis model used was a total system model of superstructure-foundation-ground, a multiple mass point system vibration model that consists of concentrated mass points and the rod members

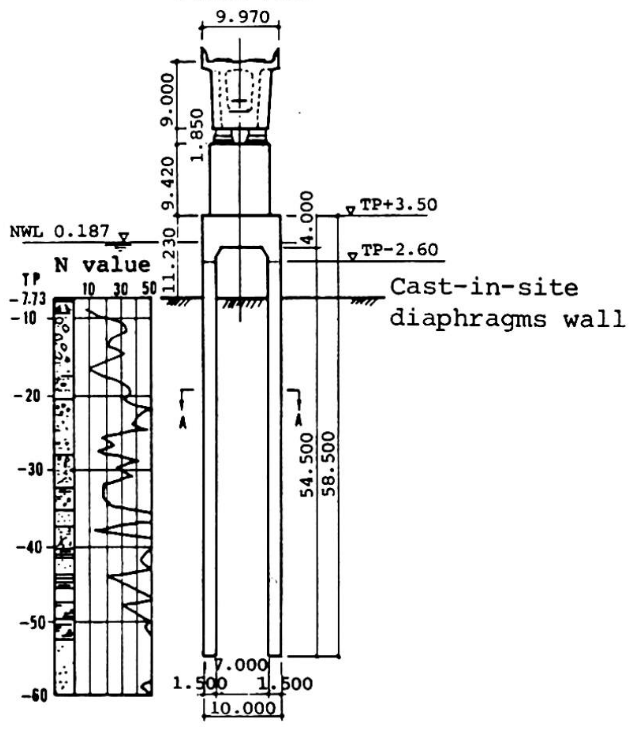

Fig-2 General drawing of superstructure and substructure at 3P (m) connecting them for structural members, and similarly, a multiple mass point grid model of a concentrated-tie spring system for ground. In order to express semi-infinite ground, a viscous damper was used to evaluate dispersion effect at an interface.

2.2 Analysis results

Table-1 shows the maximum value of response acceleration of the completion system. The reason for the response value in the transverse direction being slightly larger at both ends (1,6P) is considered due to the effect of the girder terminating there.

For the generated sectional force, a comparison was made with the ultimate strength of members and the safety thereof was checked.

The ground spring used in the seismic response analysis was made an elastic spring. Although the response value may vary slightly, this was coped with by compensating the sectional force after comparing the elastic spring and elastic-plastic spring in the static analysis. In this connection, the maximum bending moment of the elastic-plastic spring was 1.20 times that of the elastic spring at 2-4P and 1,08 times at 5P, and the maximum shearing force, 1.45 times at 2-4P and 1.15 times at 5P.

2.3 Runnability of trains

Running trains might be endangered if the amplitude of lateral vibration of the bridge becomes extremely large. To judge this safety limit for runnability quantitatively, the runnability curve as shown in Fig-3 was obtained by means of vibration analysis and model tests.

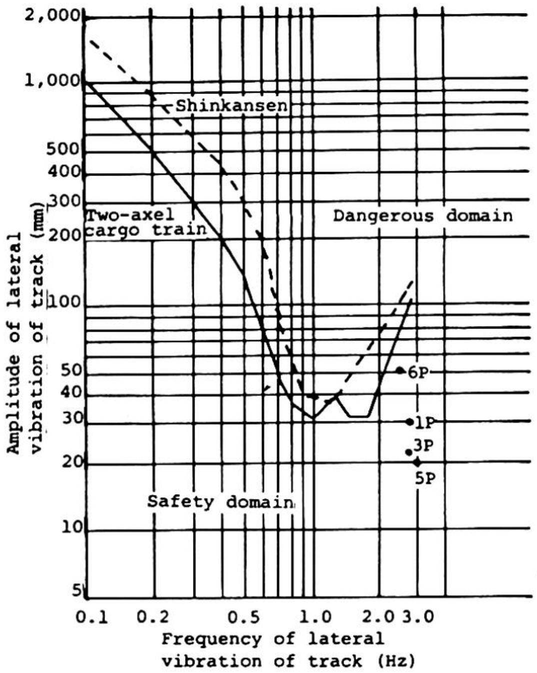

Fig-3 Runnability curve

Table-1 Maximum value of response acceleration (Gal)

		bridge axis direction	direction at right angles to bridge axis
1P	Center of girder	252	302
2P	Center of girder	247	196
3P	Center of girder	247	174
4P	Center of girder	254	194
5P	Center of girder	264	247
6P	Center of girder	268	319

The results of analysis for this bridge were plotted in Fig-3 and the safety of running trains at the time of an earthquake was confirmed.

3. DESIGN OF THE CAST-IN-SITE DIAPHRAGMS WALL FOUNDATION

Because the cast-in-site diaphragms wall foundation has an advantage which does not loosen the peripheral ground as do caisson foundations, it is considered a foundation structure that excels in bearing capacity and aseismicity. Also, there are several advantages from the viewpoint of constructability, such as it is a low noise and vibration method, it can be excavated anywhere from soft and weak soil to gravel layers and rockbeds, it is possible to excavate to a large depth, it allows mechanized construction from ground level, etc.

In consideration of these points, an cast-in-site diaphragms wall foundation was adopted as the foundation structure of this bridge, particularly because a large depth marine excavation at a water depth of 12 m was called for during construction.

The cast-in-site diaphragms wall foundation was designed by obtaining a balance between the external force and restitutive force of members and the reaction force of ground springs.

The ground springs used in this analysis were elastic-plastic springs that deform plastically as they exceed the elastic limit value. In order to evaluate the effect of plasticization of ground at the time of an earthquake on the safer side, examinations were performed using a method in which an analysis was made by applying a seismic horizontal force of 1.5 times and multiplying the sectional force obtained by 2/3 times (except axial force).
Box sections were analyzed by applying the ground reaction force obtained by the analysis of vertical direction as a load on a box rigid frame.

4. SUPERSTRUCTURE

Table-2 shows the allowable stress of PC girders and Fig-4 shows the cross-section of a girder.
The design was performed based on the cantilever erection method using travelling forms with a block length of 3.0-4.5 m in consideration of construction period, capacity of the travelling forms, constructability, etc.
Photo-1 shows the completed Kitaura-ko Bridge.

Table-2 Allowable Stress of PC Girder

SI unit

Concrete	Design standard strength σ ck		39.2 MPa
	Compressive strength at the time of introduction of pusress		27.4 MPa
	Allowable bending compressive stress intensity	At the time of introduction of prestress	17.6 MPa
		At the time of application of design load	13.7 MPa
	Allowable bending tensile stress intensity	At the time of introduction of prestress	1.47 MPa
		At the time of application of total load	0 MPa
		At the time of application of design load	0.95 MPa
	Allowable diagonal tensile stress intensity	Shear force or torsional moment	1.27 MPa
		Shear force and torsional moment	1.67 MPa
	Standard allowable bonding stress intensity (deformed bar)		1.96 MPa
PC steel material	During the prestressing		0.80 σpu or 0.90 σpy
	Immediately after prestressing		0.70 σpn or 0.85 σpy
	At the time of application of design load		0.60 σpu or 0.75 σpy

4.1 PC Steel

In general, one kind of PC steel is used in a PC continuous girder, but in this bridge, PC steel bars, SBPR95/120, were used to resist for the dead load of cantilever erected girder and a steel stranded wire, SWPR7B12T15.2 for train load, etc. after the completion of the bridge.

This was done to reduce the necessary quantity of steel material, thereby lowering the cost of construction and improving constructability by making use of the features of steel bars and steel stranded wires. In other words, it is possible to lay out the steel bars delicately and the tensioning tools can be small and highly maneuverable. In addition, because the stranded wires have a large tensioning force, the number of tensioning and grouting works can be reduced, bending layout is easier, and as they are inserted after the casting of concrete, the risk of damage and rusting of steel is smaller.

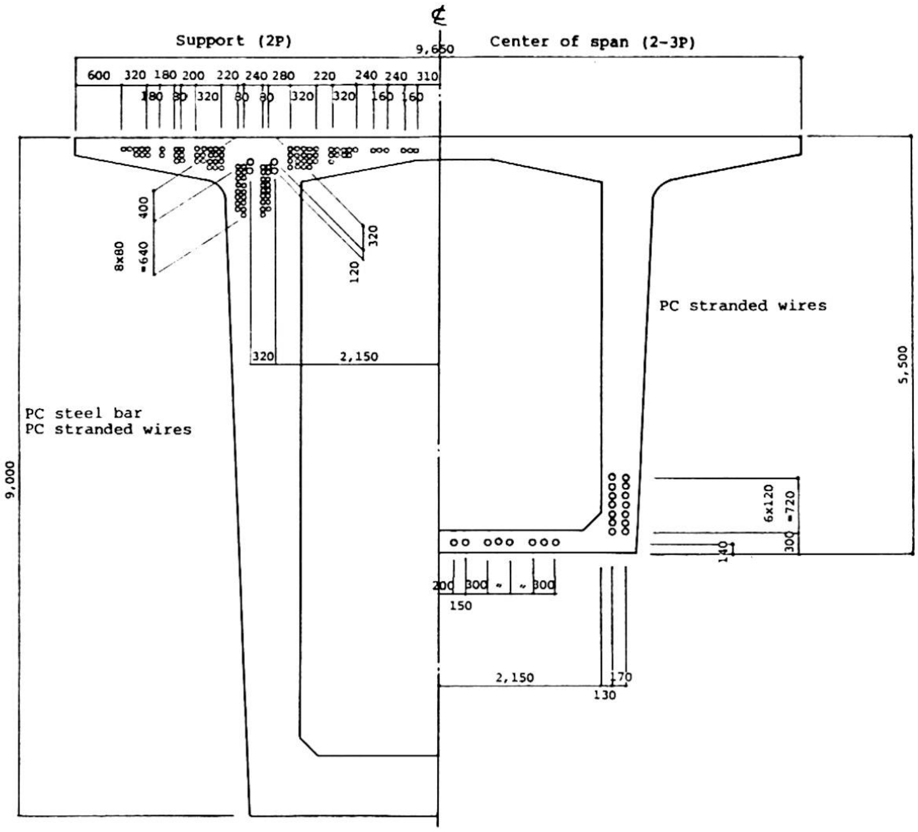

Fig-4 Cross section of girder and layout of PC steel bar and stranded wires (mm)

Photo-1 The completed Kitaura-ko Bridge.

As a result, the quantity of PC steel in the longitudinal direction was reduced by 20%, about 80 tons, also serving to improve the constructability.

4.2 Low friction sheath

Considering the fact that the length of a PC tendon was to be 130 m, the low friction sheath processed by fluoride was used. The tensile force was obtained by using the following formula. The design was performed using the coefficients of friction as $\mu = 0.3$, $\lambda = 0.004$ for the ordinary sheath and $\mu = 0.25$, $\lambda = 0.0033$ with reference to the test results, etc. for the low friction sheath.

In the construction, the PC tendon was tensioned as early as possible after insertion so as to reduce the rusting. As a result, the coefficient of friction was made smaller and the effect was fully demonstrated.

$$Po = Pe^{-(\mu\alpha + \lambda l)}$$

where,

- Po : Tensile force of PC steel material at the position of l (m), the length of steel material, from the position where the tensile force is given
- P : Tensile force of PC steel material at the position where the tensile force is given, that is, the position of the jack
- α : Angular change (radian) in the length of l (m) of the PC steel material
- l : Length of PC material (m) measured from the position where the tensile force is given
- μ : Coefficient of friction per unit angle change (radian)
- λ : Coefficient of friction per unit length (m)

5. POSTSCRIPT

The Kojima-Sakaide route will be open for traffic for highway and railway on April 10, 1988 and train which shuttles between Honshu and Shikoku will run through the Kitaura-Ko Bridge. This paper introduced how to examine the runnability of train during earthquake, construction of cast-in-site diaphragms wall foundation and PC girder with two types of PC steel. We are convinced that these new technologies will contribute for more economical construction and seismic resistant design for long-span railway bridges.