Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 64 (1991)

Artikel: Prestressed concrete horizontal arch bridge
Autor: Ebana, Ryoh / Hoshino, Kunio / Kutuzawa, Keiji
DOI: https://doi.org/10.5169/seals-49310

Prestressed Concrete Horizontal Arch Bridge

Pont en arc en béton précontraint, avec arc dans un plan horizontal

Vorgespannte Betonbrücke mit horizontalem Bogen

Ryoh EBANA
Deputy Director
Fukushima Pref. Gov.
Fukushima, Japan

Ryoh Ebana, born in 1935, received B.S. at Chuou Univ. He has been engaged in Public work dep. of Fukushima Pref. Gov. since 1959.

Kunio HOSHINO
Dr. Eng.
Hoshino Bridge Design & Eng. Co.
Tokyo, Japan

Kunio Hoshino received B.S. at Tokyo Univ. and Dr.-Eng. degree at the Univ. of Stuttgart, Germany. Consulting Engineer mainly in the field of bridges for many years with Hoshino Bridge Design & Engineering Co.

Keiji KUTUZAWA
Mgr
Fukushima Pref. Gov.
Fukushima, Japan

Keiji Kutuzawa, born in 1934, received B.S. at Chuou Univ. He has been engaged in Public work dep. of Fukushima Pref. Gov. since 1958.

Takeshi SUGIMOTO
Assist. Mgr
P.S. Corporation
Sendai, Japan

Takeshi Sugimoto, born in 1947, received B.S. at Nagoya Institute of Technology. He has been engaged in bridge engineering in P.S. Corporation since 1972.

SUMMARY
This article concerns design and construction of a unique bridge. This bridge is 9 span prestressed concrete curved continuous box girder bridge. Both ends of the bridge are fixed in the horizontal plane. Thus the bridge acts as a horizontal arch for seismic force and temperature change. It was constructed by the incremental launching method.

RESUME
Cet article décrit l'étude et la construction d'un pont exceptionnel. Il s'agit d'un pont à poutre-caisson en béton précontraint, comprenant 9 travées continues et incurvées. Les deux culées extrêmes du pont sont fondées sur un plan horizontal. De la sorte, il se comporte comme un arc horizontal sous l'effet des sollicitations sismiques et des changements de température. Il a été construit par encorbellement.

ZUSAMMENFASSUNG
Dieser Beitrag behandelt Entwurf und Erstellung einer einmaligen Brücke. Es handelt sich um eine gekrümmte durchlaufende Hohlkastenbrücke. Beide Enden sind gehalten und die Brücke wirkt als horizontaler Bogen für Erdbeben- und Temperaturbeanspruchungen. Sie wurde im Taktschiebeverfahren erstellt.

1. INTRODUCTION

The Yokomuki Bridge is located in a mountainous district in the northern part of Honshu in earthquake-prone Japan. This bridge is a 9 span PC(Prestressed Concrete) curved continuous box girder bridge.

Both ends of the bridge are fixed in horizontal plane. Thus the bridge acts as horizontal arch for seismic force and temperature change.

This bridge was constructed by the incremental launching method with severe construction condition.

This paper summaraizes the design and construction aspects of the Yokomuki Bridge.

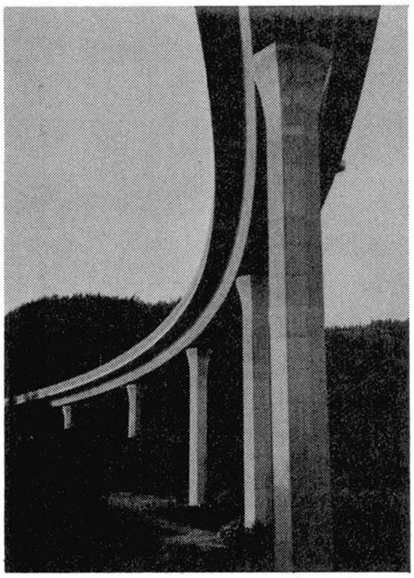


Fig.1 Yokomuki Bridge

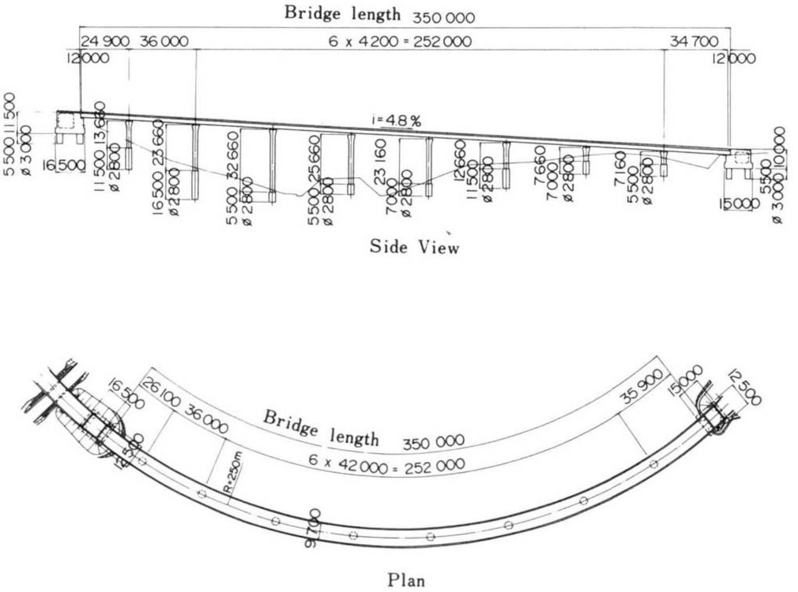


Fig.2 General View of the Bridge

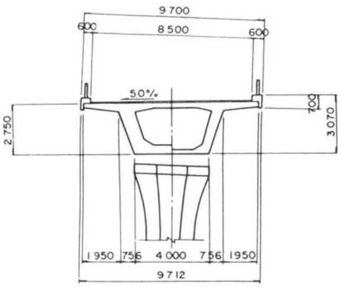


Fig.3

Cross-section of the deck

2. CONSTRUCTION CONDITION

- Location : bridge across the Takamori River in Fukushima Pref. in Japan, and locates in Bandai-Asahi national park
- Road type : national highway
- Bridge length : 350 m
- Main span : 42 m
- Radious of curvature : 250 m
- Longitudinal slope : 4.8 %
- Effective deck width : 8.5 m

- Cross slope of deck : 5.0 %
- Seismic coefficient : 0.15
- Structure of deck : 9 span PC continuous box girder
- Vertical bearing
  - at abutments : fix with steel bearing
  - at middle piers : all direction movable with rubber ring bearing
- Horizontal bearing at abutments : rubber bearing with prestressing tendon
- Soil : rock of andesite and tuff
- Foundation : in-situ concrete pile
- Client : Fukushima Prefectural Goverment
- Designer : Hoshino Bridge Design & Engineering Co.
- Contractor : Joint Venture of P. S. Corporation & Aizukokensya Co., Ltd.

The bridge has been completed in November 1990.

3. DESIGN

3.1 Structural characteristics

To make good use of the above-mentioned construction conditions, the both ends of the bridge are fixed to abutments in the horizontal plane. Then the bridge acts as a arch in horizontal plane, not as curved beam for seismic force and temperature change.
Compared to curved beam, the advantages of this system are as follows :

- at earthquake : horizontal force acting on the girder is transmitted almost to the abutments as axial force, thus enabling to reduce the horizontal force at middle piers. Fig.4 shows the typical behavior of arch system and curved beam against the horizontal force.
  Furthermore in the case of flexible piers, bending moment of girder due to horizontal force is smaller than that of curved beam.
- The elongation of girder due to temperature etc. will turn into the rise deformation of horizontal arch.

The design for traffic load etc. is almost similar to common continuous bridges, so we mention here mainly about horizontal behavior of this bridge.

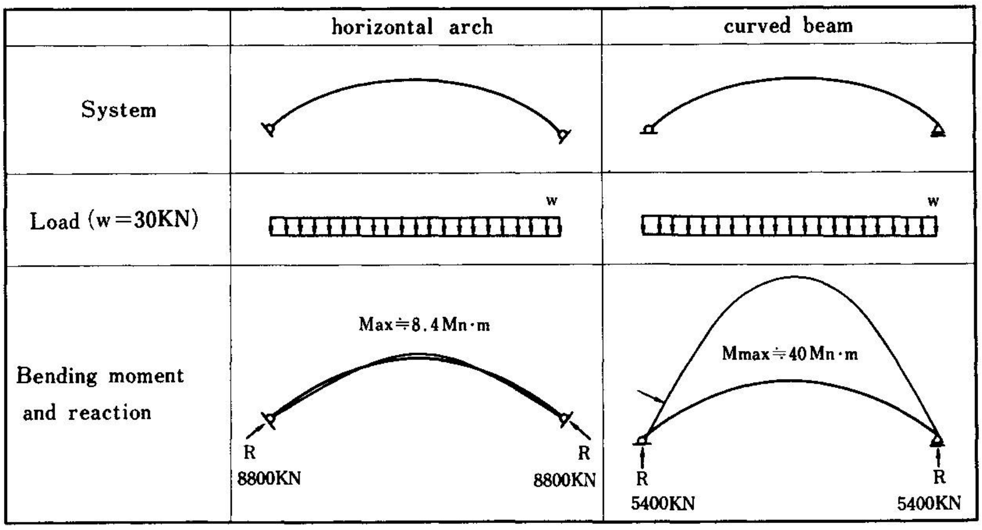
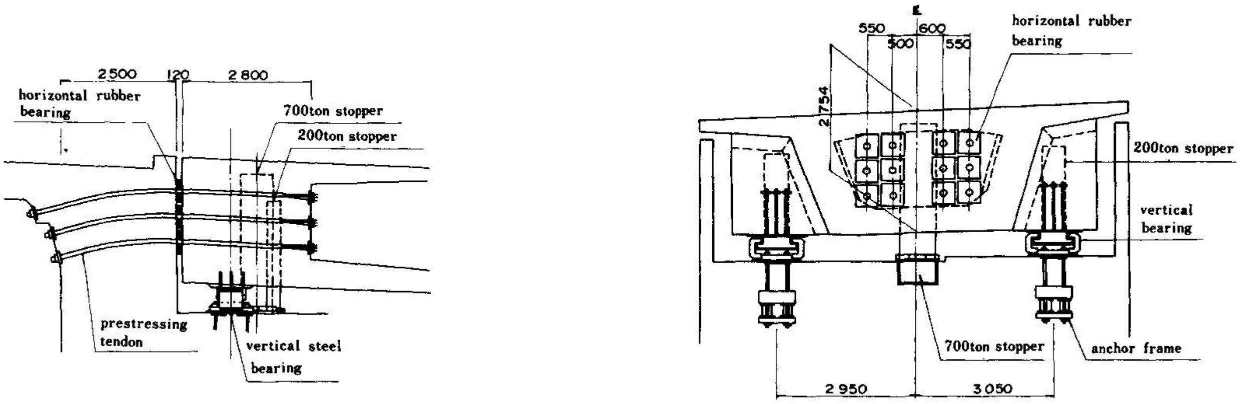


Fig.4 Schema of static equilibrium

3.2 Design outline

To satisfy the construction condition and to realize the above conception, the bridge was designed as follows:

- The middle piers are designed slender and flexible.
- The both ends of the bridge are fixed to abutments in the horizontal plane with rubber bearing and prestressing tendon(Fig.5). And the abutments and its foundation are stiffened against the arch reaction.
- The bearings at pier are one-point rubber ring bearing in order to move in all direction.
- The overall girder is reinforced with re-bar and prestressing tendon against torque and axial tension force.
- The expansion joints at abutments are small and simple.
- The bridge was designed to construct by incremental launching method developped by F. Leonhardt and W. Baur.



(side view) (cross section)

Fig.5 Bearing at abutment

4. CONSTRUCTION

4.1 General

The bridge was divided into 25 segments and each length is 14 m.
Fabrication and launching operation of segments was carried out at back site of the lower abutment(A2). Standard cycle of launching was 8 days.
The total weight of the girder is 6400 tons and the capacity of launching jack was 800 tons. Measured friction between stainless plate and PTFE sliding shoe was about 3 %.

Horizontal force during the construction is greater than completed condition because of curvature and support condition, so we had stiffened the piers temporary as follows:

- To limit the logitudinal displacement to about 30 mm at the top of pier, two 270tons stay cables were prestressed between the ground and the head of the pier(Fig. 6,7).

- To resist the tangential force to launching direction due to curved bridge, stiff walls were built at both sides of P7 pier which is the 2nd pier from the launching abutment(Fig.8).

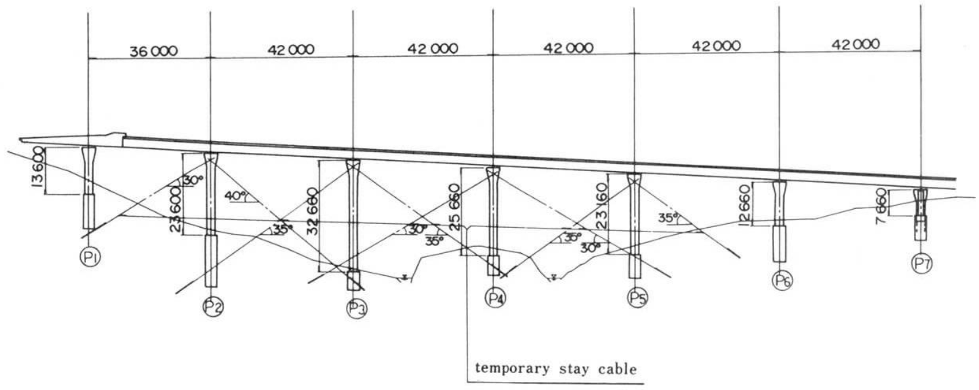


Fig.6 Temporary stay cable arrangement

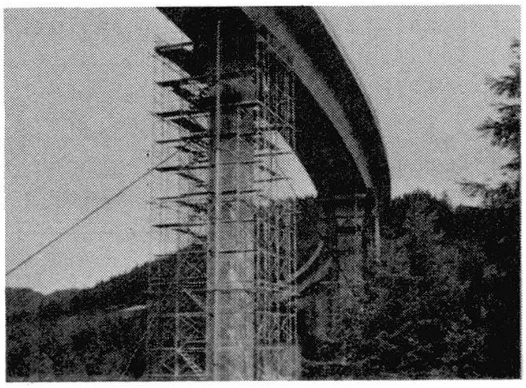


Fig.7 Temporary stay cable

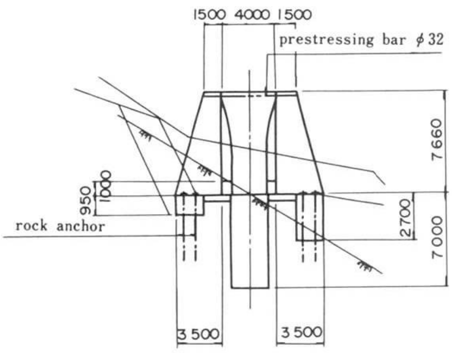


Fig.8 Stiff wall at P7

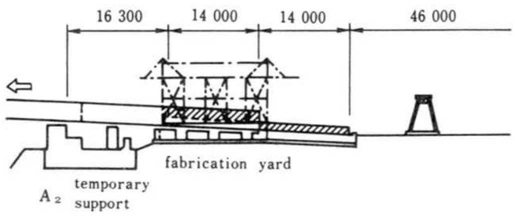


Fig.9 Fabrication yard

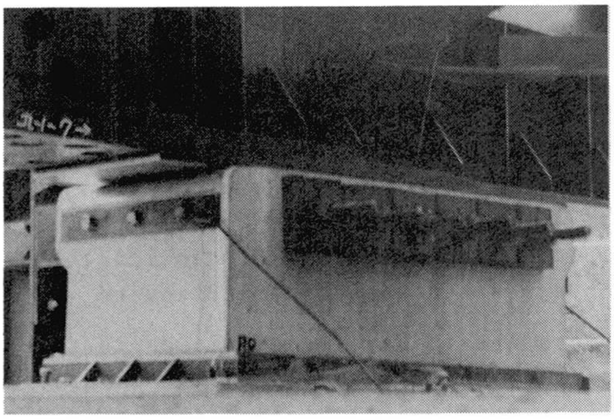


Fig.10 Temporary shoe for launching

4.2 Measurement during construction

The following mesurements are performed to control the quality of the bridge and to ensure the safety during construction.

- launching direction : The electro-optical surveying equipment and portable computer checked current positions on real time and launching tracks were corrected by 100ton jack on stiff wall. Fig.11 shows track positions in some construction phase. From the Fig.11 it is clear that the launching track tends to move towards the outside of the curve.
- displacement of piers :
- force of temporary stay cable :
- tensioning force of launching jack :(Table.1)

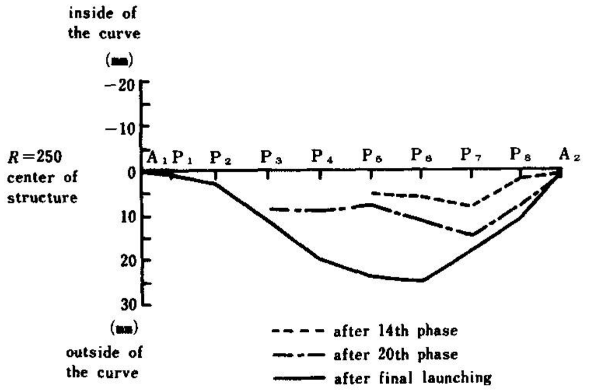


Fig.11 Track history

phase	launching length L (m)	launching weight W (MN)	launching force Pj (MN)	friction coefficiert μ (%)
2nd	27.9	4.6	0.62 0.52	8.7 6.4
10th	133.9	22.6	2.16 1.76	4.5 2.7
20th	265.9	43.7	3.53 3.19	3.3 2.5
25th (end)	335.9	55.6	3.92 3.58	2.3 1.6

upper : maximum value
lower : average value

Table.1 Jacking force at launching

5. COST

In comparison with conventional continuous bridges, the cost of this bridge was more economical mainly because of slender piers and its foundations.

6. CONCLUSION

We have presented the design and construction of a unique bridge. Horizontal arch concept was effective for these construction condition. It was a first experience in Japan to construct the bridge under such severe conditions i.e. with 350m bridge length, R=250m curvature and slender piers. The bridge was completed as scheduled.

The piers are rather slender in earthquake-prone Japan. But there are many ideas to ensure the safety of the bridge. The completed bridge has a excellent profile and blend into the landscape of national park.