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Design and Construction of Prestressed Concrete Curved Railway Bridge Consisting of Precast Concrete Blocks

Projet et construction d'un pont courbe de chemin de fer par précontrainte de blocs préfabriqués en béton

Entwurf und Konstruktion einer vorgespannten gebogenen Eisenbahnbrücke aus vorfabrizierten Betonblöcken

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1. Preface

The construction of the track addition of the OHU Trunk Line is making progress to increase transport capacity of the trunk lines on the basis of the Japanese National Railways's Third Long Term Plan.

The construction of the Yoneshiro-gawa railway bridge was intended as a result of the track addition work between Tomine and Futatsui Station. This bridge is of prestressed concrete continuous girders with 3 spans each 56.3 m long, and the first prestressed concrete curved bridge for the Japanese National Railways.

The decision made to open the traffic of this section Tomine - Futatsui from July 1969 necessitated to make studies of various problems on the structural design and construction requirements because the construction term has become limited and a major part of the work was required to carry out during winter. These studies led us to adopt the staging erection method attaching the precast concrete blocks for the project. (Fig-1)

This method is to carry the pre-manufactured precast concrete blocks to the project site and arrange on the temporary stagings, and after joint concrete hardened prestress process is applied to the girders. This gave us the benefit of shortening the work period.

2. Plan

(1) Route selection

As the existing Yoneshiro-gawa bridge is in the curve section with 400 m in radius, it is necessary for the new bridge to improve the align by enlarging the radius.

Two plans are considered: one is to cross the river with curve at some distance from the existing line (curve plan), and the other to cross in straight line (straight plan).

On comparative study of the required length of bridge and tunnel, it was found that the straight plan needs more cost of construction than the other. Further, from the viewpoint that the larger curve radius is advantageous for the girder design, the plan to cross the Yoneshiro River at a curve radius of 800 m was adopted (Fig-2).

(2) Terrain and geology

The terrain of the erection point is a narrow part between the Takanosu basin and the Noshiro plain, and the Yoneshiro River is winding this constriction part.

A hard and sound tuff, outcrops of which appeared on the river bank of Aomori side, enable us to utilize it for the foundation of abutment of that side. Although the nature of this tuff layer was unable to ascertain at the pier No. 5, because of a sudden increase in its depth toward Fukushima side, well compacted gravel layers were found on surface layers (See Fig-1).

(3) Meteorology

Since a major part of the work must be carried out during cold winter, consideration was given to the meteorological conditions. The lowest temperature in winter at the bridge site is -15°C, and not few days register below zero even in the daytime. This area has heavy snowfall with strong wind accompanied by snowstorm peculiar to the district. Therefore, execution must be made under severe weather conditions.

(4) River

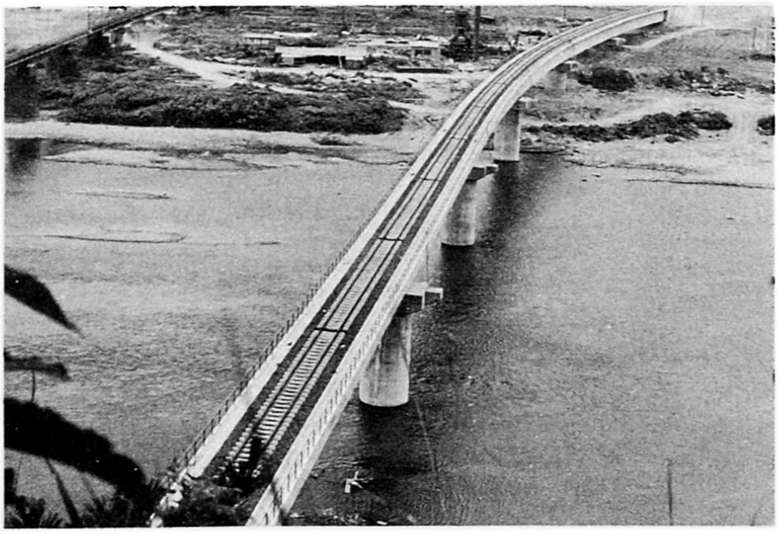
The Yoneshiro River having 6,000 cms of estimated high-water discharge is subjected to floods due to thaw during a period from the end of March to April, and to heavy rainfall and typhoons during July to September. Generally, May, June and October to March are dry season.

(5) Structural aspect and execution method

a) Investigation for structural pattern

After making discussions with Administrater of the river, comparative studies were made on several types of bridge under the requirement that the length of each span be more than 55 m. The concrete girder type was judged to be most advantageous in view of the future tendency of track and maintenance of girders. However, considering that this type requires to perform its concrete work under unfavorable weather conditions, investigations were made how to overcome the anticipated difficulties.

If, however, the prestressed concrete jointing precast block method is applied, the concrete blocks can be manufactured before winter. Even during winter, it is possible to make the blocks of good concrete in a temporary shed



General view

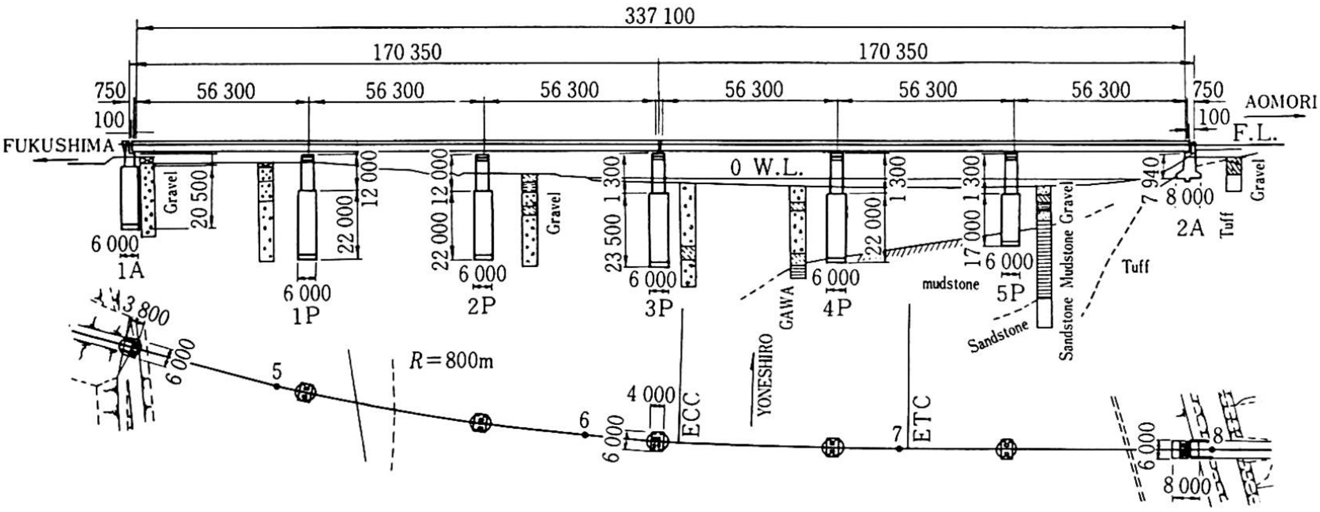


Fig.1 Side view

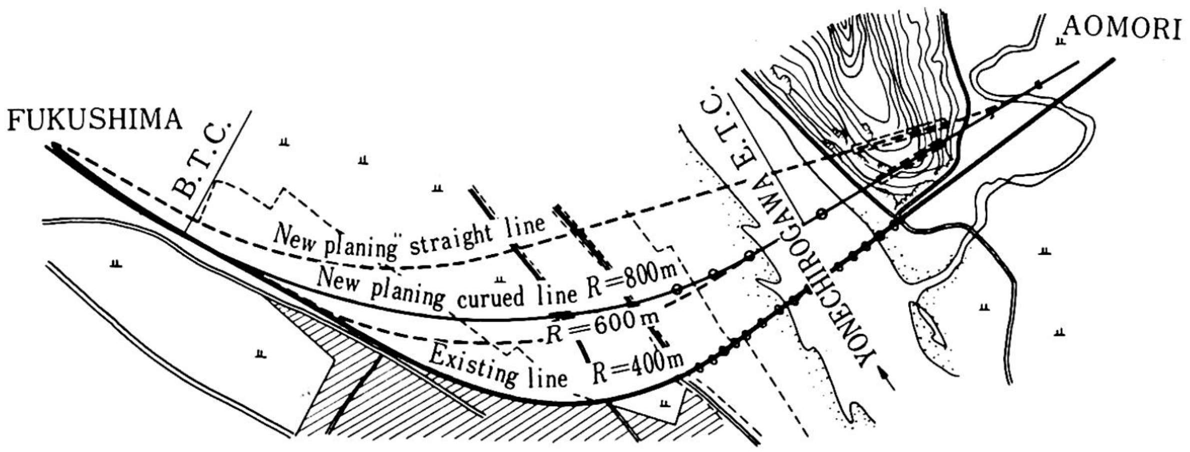


Fig.2 Comparison of two plans

under adequate control. This means shortening of the construction period. Hence, it was considered that the precast block process is most advantageous for construction of the Yoneshiro-gawa railway bridge.

b) Investigation for the joints of blocks

For the joint fill material, resin, mortar, and concrete were studied.

c) Determination of structural pattern and execution method

As a result of a thorough studies of joint structure and execution method, the staging erection method attaching precast concrete blocks with the cast-in-place concrete joint was adopted.

The blocks were manufactured for straight line girders. In application of these blocks to the curved girders, the blocks were placed on the bent along the curved line, making the joints to trapezoid shape.

In order to ensure safety against floods, the work for each continuous girder was divided into three sections (span), and proceeded from one to another, starting with that of Aomori side (See Fig-3). The length and weight of each concrete block was decided within 5 m and 60 t.

3. Design

(1) Outline of design

Standard section of this girder is shown in Fig-4. The characteristics may be summarized as follows:

a) This is a prestressed concrete continuous girder bridge of precast concrete blocks jointing with concrete joints.

b) Adopted three spans of continuous curved girders.

c) Seismic horizontal force on the continuous girder of Fukushima side was distributed among and supported by each pier.

For c), special supporting structures were devised. As fatigue tests proved that the conventional method can assure a sufficient shear strength of the precast block girders, no special consideration was given. As to the bending stress in concrete, however, it was so designed that more than 5 kg/cm^2 of compressive stress will remain on service.

(2) Design of support

a) Structure of shoe

Supports have bearing plates with special structures of shear key of upper and lower shoes, without anchor bolts. The shear key, as shown Fig-5, has box-shaped blocks projecting upward and downward, and after its hollow portions being filled with concrete, was embedded within girders and piers. Advantages of this key is in that no anchor bolt is needed, and that sufficient shearing resistance is ensured.

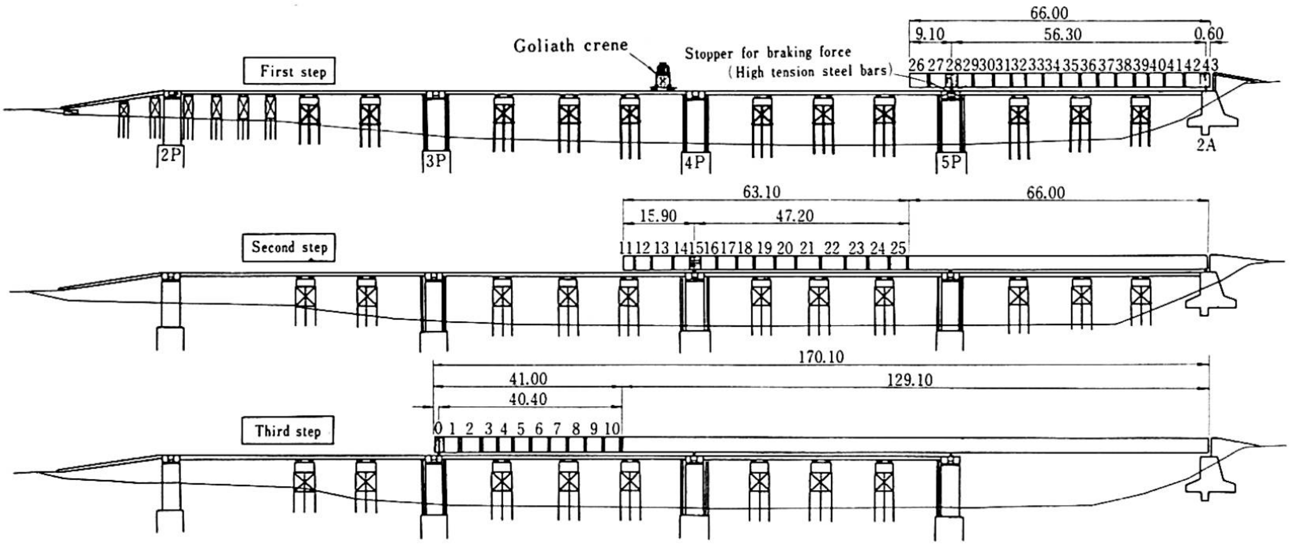


Fig.3 Schedule of execution

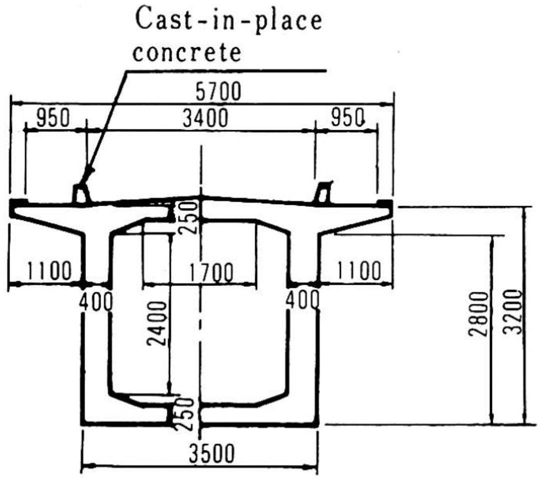


Fig.4 Standerd section

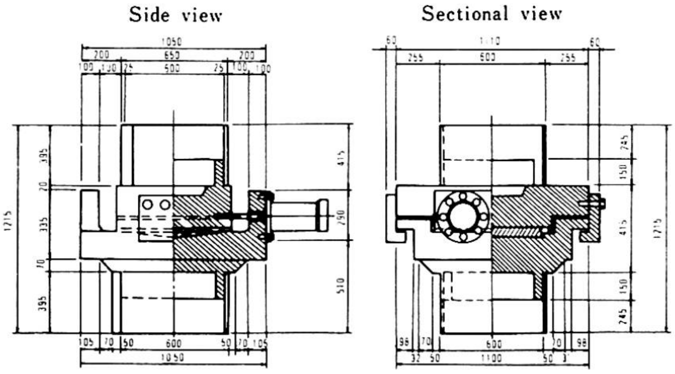
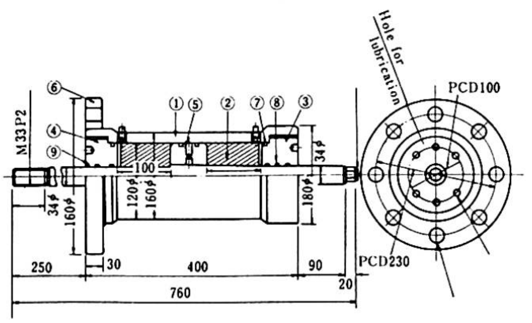


Fig.5 Shoe



① Cylinder
② Ram
③ Cylinder collar
④ Bottom
⑤ Ram collar
⑥ Flange
⑦ O-shaped ring
⑧ O-shaped ring
⑨ Scraper

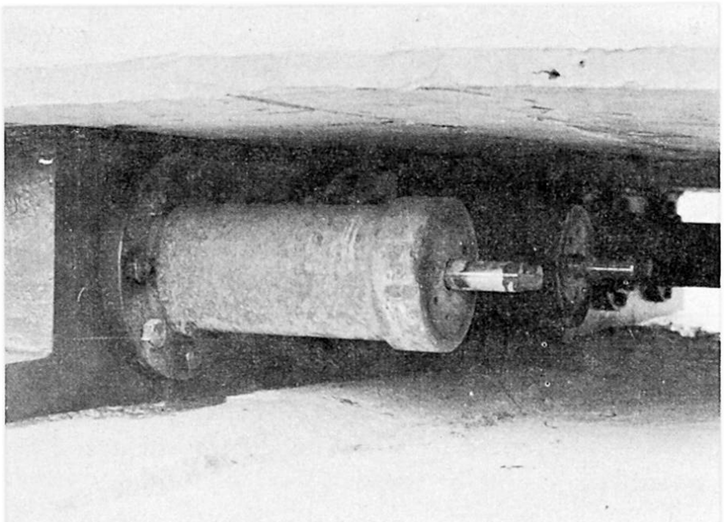


Fig.6 Oil damper

b) Oil dampers

As a result of the fact that ground of Fukushima side was not too strong to construct continuous girders, it was unreasonable to carry the entire seismic horizontal force by a single pier, then it became necessary to share the force by all supports.

Locality relation between upper and lower shoes usually varies with the influence of temperature, creep, and drying shrinkage. Consequently, if an earthquake occurs, no dispersion of horizontal force takes place, but the force concentrates at a certain pier.

In order to avoid occurrence of such situation, dampers as shown in Fig-6 were provided to have such mechanism that a sudden displacement never happens on the upper shoes without transmission of horizontal force to the lower shoes. The dampers provided herein, therefore, do not aim at damping but at equal dispersion of the horizontal force. The dampers show almost no resistance to a slow movement of the piston, and resist against a sudden action of it.

In this design, a maximum horizontal force is estimated at 100 tons per each damper. Each shoe has two dampers.

4. Execution

(1) Manufacturing of blocks

Fabrication of formwork, sheath, and reinforcement bars is made within a temporary shed movable on block manufacturing yard.

Concrete placing and curing were carried out within the shed, holding its temperature with jet heaters. Heat control was made only one day, and curing was made more than two days.

Table-1 shows a work schedule at a manufacturing rate of two or three blocks in one process, and one operation circle constituted 13 days.

(2) Girder erection

a) Temporary stagings

The girder of the water flowing portion was constructed on the beam supports that can bear the lord of goliath crane carrying the concrete block (Fig-7).

b) Transport of blocks

Blocks, after being hauled from the manufacturing yard through slopeway were loaded on goliath crane, and transported to the predetermined places. The block transporting capacity was five blocks in average per day.

c) Execution of joints and supports part

Execution of joints between concrete blocks and supports part was performed by placing concrete after connecting sheaths, formworks, and reinforcement bars.

To cure concrete, the joints were covered with sheets, holding temperature by two units of jet heaters.

Classification of work	Days 0 1 2 3 4 5 6 7 8 9 10 11 12 13
Out-side formwork	4
Sheath and reinforcement bar	2
In-side formwork	2
Reinforcement of upper slab	1
Concrete placing	1
Curing	2
Form removal	2

Table 1 Work progress for concrete block manufacturing

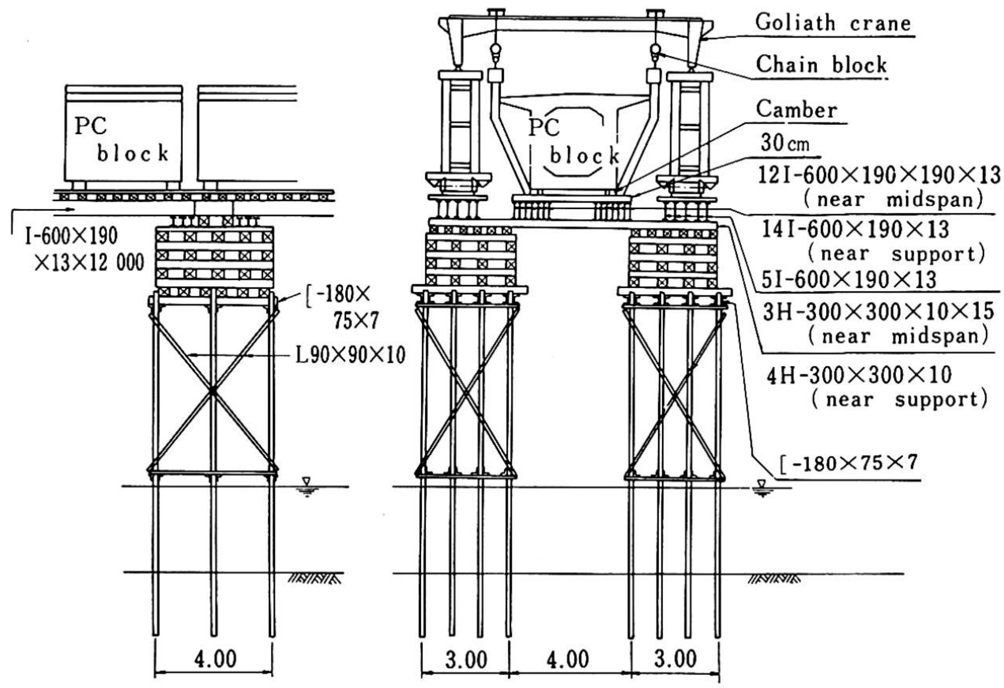
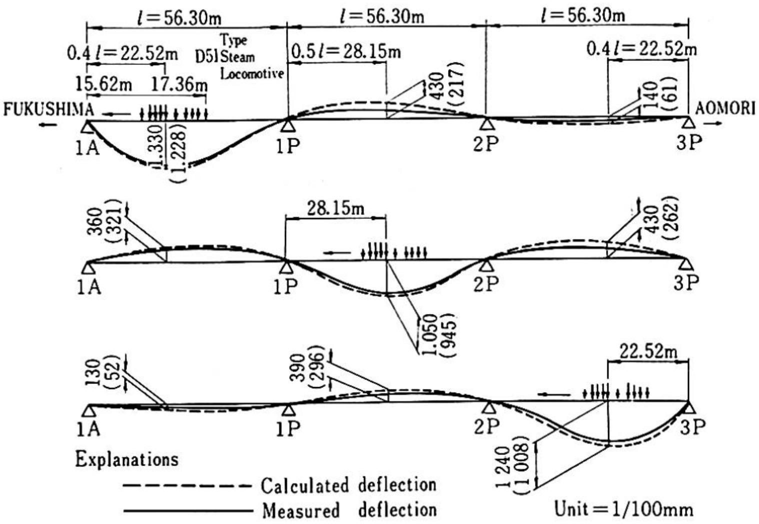


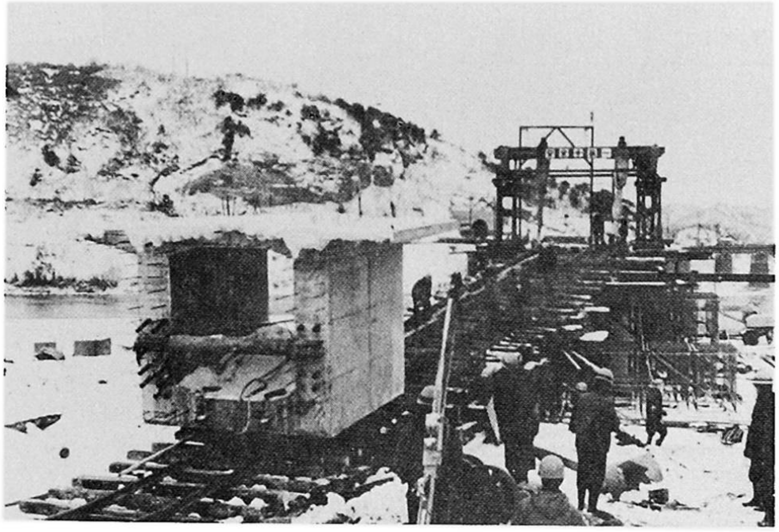
Fig.7 Temporary staging



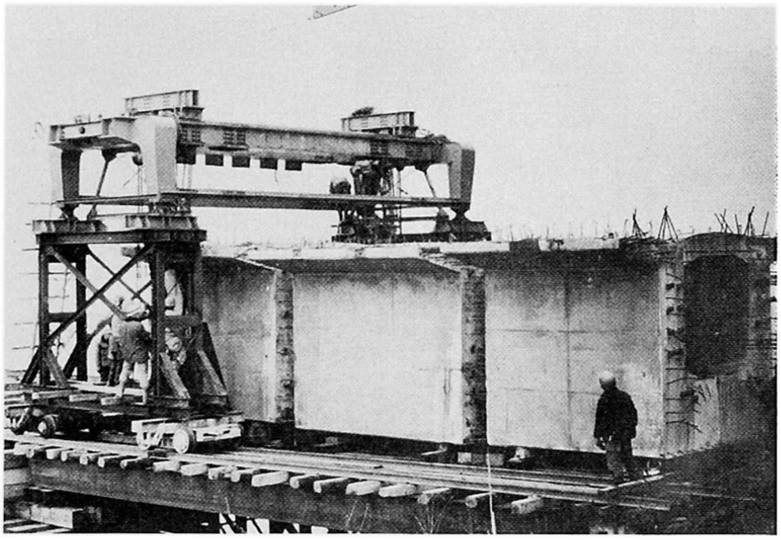
Notes : (1) The deflections are calculated with E_c=350 000kg/cm²

(2) ( ); Measured deflection

Fig.8 Measured deflections of the girder



Precast block on the slopeway



Transportation of precast blocks by goliath crane

Precast blocks on the temporary stagings

5. Loading test of girders

It is necessary to exercise to confirm whether the completed structures are sound or not. For this purpose, deflection tests of girders were conducted.

For the load test, D51 type steam locomotive was employed. The results of the tests are illustrated in Fig-8. The actually measured values are somewhat smaller than those of calculation.

Since the calculation values are those which were designed estimating the elastic modulus of concrete at 3.5×10^5 kg/cm^2 and the strength of concrete at 400 kg/cm^2, the concrete strength of the girders can fully satisfy the design stress.

6. Conclusion

This method is disadvantageous in that with a need of long period of time for installation of the temporary stagings, it tends to cause a delay in its completion if the staging work takes a longer time than scheduled. But advantages of this method may be mentioned as follows:

(1) This method can shorten the construction term especially the period of the temporary stagings, and it is possible to proceed the girder work even in winter or availing dry season.

(2) Because of the fact that this method is easy and reliable in comparison with the method of the cast-in-place concrete in quality control, especially efficient and effective method in winter season.

(3) In placing concrete, the cast-in-place method frequently confronts with the problem of settlement of stagings. If, however, this method is applied, as the settlement can be easily adjusted in advance by means of jack, it may be a matter of no consideration about settlement of stagings.

(4) This method needs only simple transport facilities of precast blocks in addition to the equipment for cast-in-place method, and no special installation and material is required for erection of girders.

Summary

This railway bridge is of prestressed concrete continuous girders with 3 spans each 56.3 m long and total length 337.8 m, and is existing in the curve section of 800 m in radius.

Since a major part of the work must be carried out during winter, the staging erection method attaching the precast concrete blocks which are premanufactured on manufacturing yard is adopted.

To distribute a seismic horizontal force to each pier, specially designed dampers are installed.

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