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Construction Technology of Long Span Concrete Arch Bridges

Techniques de construction des ponts en arc en béton de grande portée

Bautechnologie bei Betonbogenbrücken langer Spannweite

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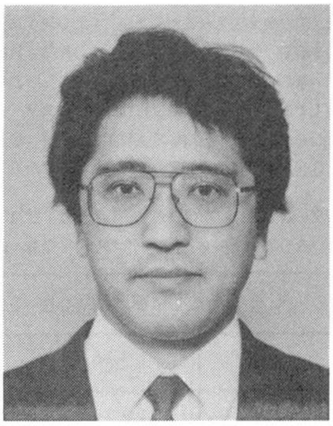


SUMMARY
The construction methods used in long span concrete arch bridges in Japan are illustrated with regard to the span length and the structural types in the four given examples. The various measures taken for the adjustment of stress and the improvement of aseismicity during erection are also introduced. The future development of construction technology of concrete arch bridges is surveyed as well.

RESUME
Les méthodes de construction des ponts en arc en béton de grande portée utilisées au Japon sont illustrées par les quatre exemples (en se référant à la portée et aux types de structure). Les diverses mesures pour l'adaptation des contraintes et l'amélioration de la résistance antisismique pendant la construction figurent dans cet article qui donne également un aperçu du développement futur des techniques de construction des ponts en arc en béton.

ZUSAMMENFASSUNG
Die Konstruktionsmethoden von Betonbogenbrücken langer Spannweite werden anhand der Spannweite und des Strukturtyps von vier Beispielen dargestellt. Gleichzeitig werden auch die verschiedenen Massnahmen zur Regulierung der Belastung und Verbesserung der Erdbebensicherheit während der Montage vorgestellt. Darüberhinaus wird ein Überblick über zukünftige Entwicklungen der Bautechnologie von Betonbogenbrücken gegeben.

1.BACKGROUND

The construction of long span concrete arch bridges in Japan has been enabled with adopting various erection methods. It may be said that these technology are based on the technology and the experiences of the cantilever erection of prestressed concrete long span girder bridges since 1958. Seven long concrete arch bridges have been constructed by the cantilever erection: first the Hokawazu Bridge in 1974 to the latest the 235m-span Beppu-Myouban Bridge in 1989 (Table 1). The three erection methods have been used separately or with their combination.

The first is the truss method: a bridge is constructed while truss structure is formed with arch ribs, vertical columns, stiffening beams, diagonal members and so on. The second is the pylon method: arch rib is suspended with cables from a column installed on a arch abutment. The third is the Melan method: arch rib is formed by preceding steel member (Melan) in order to reduce section forces before arch rib closure.

These methods have realized the growing-longer of span length and the reduction of erection cost with combination, such as pylon-Melan method or truss-Melan method according to the erection condition. This paper is to introduce the construction technology of long span concrete arch bridges in Japan and to examine the possibility of future growth, on the four characteristic bridges among the seven.

Table 1 Long span concrete arch bridges by cantilever erection method in Japan

Bridge Name	Completion Year	Arch Span(m)	Truss	Pylon	Melan
Hokawazu Bridge	1974	170	0		
Taishaku Bridge	1978	145		0	0
Akayagawa Bridge	1979	126	0		
Usagawa Bridge	1982	204		0	0
Nakatanigawa Bridge	1988	100	0		
Maruyama Bridge	1989	118		0	0
Beppu-Myouban Bridge	1989	235	0		0

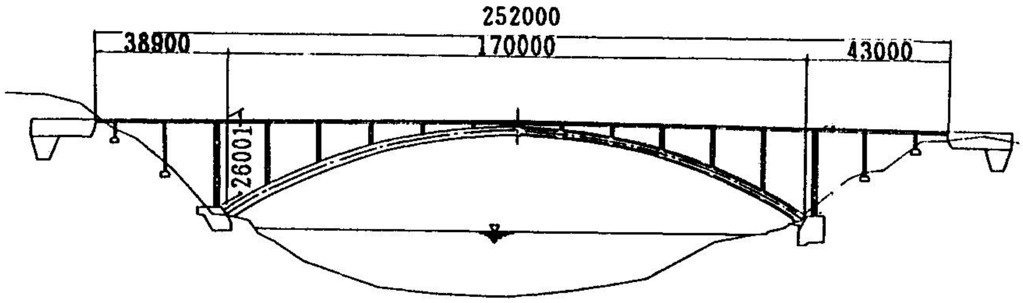
2.CONSTRUCTION TECHNOLOGY

2.1 Hokawazu Bridge

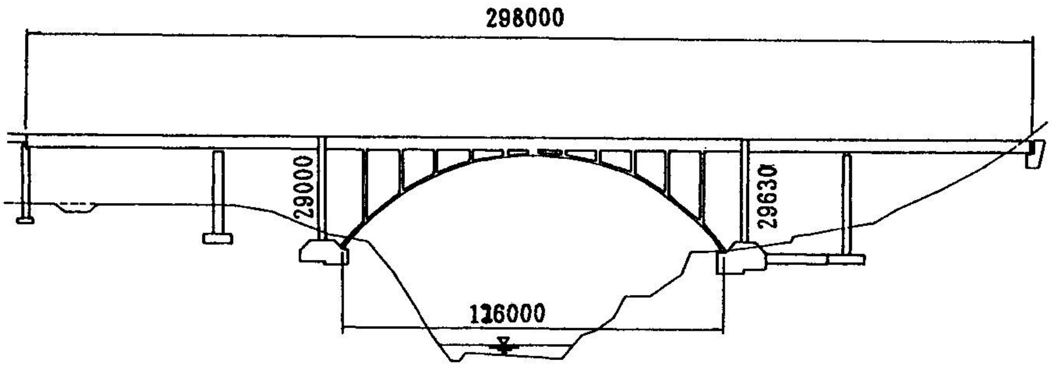
The 170m-arch-span Hokawazu Bridge was completed with the truss method in 1974; the arch rib was manufactured with a vorbauwagen, and stiffening prestressed concrete girder was manufactured with span-by-span movable form carrier; diagonal members of prestressing bars formed truss structure during erection. External cables on the stiffening girder fixed it to the abutment by prestressing, and the weight of the abutment coped with over turning moment. The tensil stress of the arch rib and the stiffening girder during erection was reinforced by the external cables. These cables were removed after closing.

Procedure of the cantilever construction:

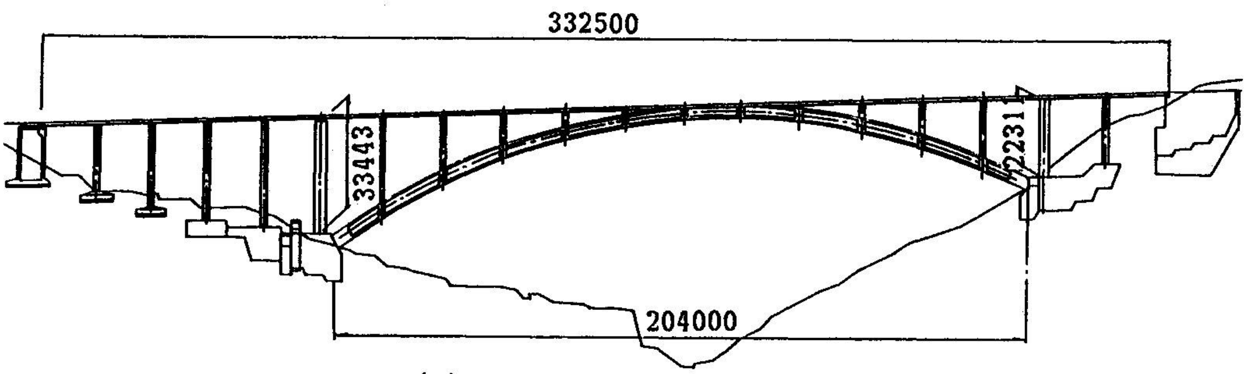
- placing concrete of arch rib
- tensioning the external cables on the arch rib
- moving the vorbauwagen
- tensioning the diagonal members
- construction of the vertical column
- placing concrete of the stiffening girder
- tensioning the external cables on the stiffening girder
- movement of stiffening girder formwork



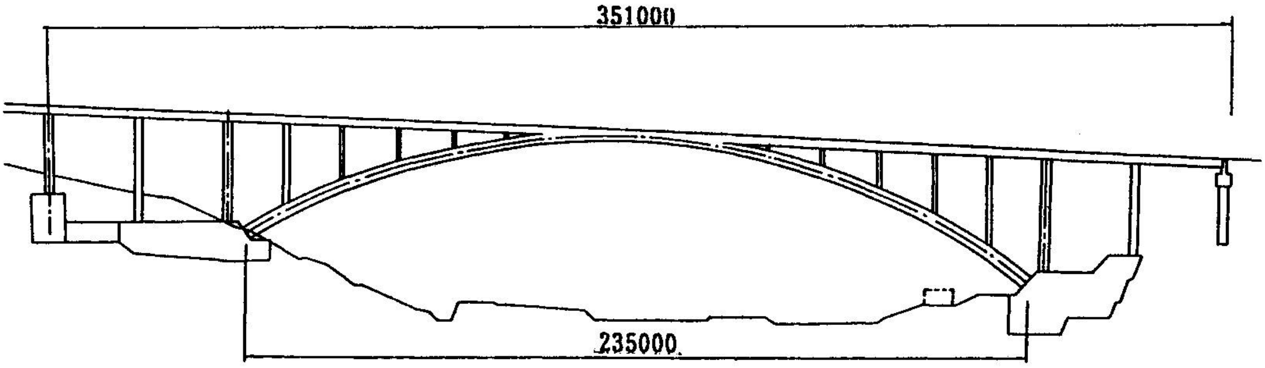
(1) Hokawazu Bridge



(2) Akayagawa Bridge



(3) Usagawa Bridge



(4) Beppu-Myouban Bridge

Fig. 1 General view of 4 bridges

2.2 Akayagawa Bridge

The 126m-arch-span Akayagawa Bridge, a deck Langer bridge, was completed with the truss method in 1979; the stiffening girder and the arch rib were concreted with the same vorbauwagen, and the cantilever erection was executed forming truss structure with vertical columns and tensioned diagonal members. The over turning moment during cantilever erection was supported by the weight of the sidespan girder and backstay. This backstay was a concrete member, in which prestressing tendons were enfolded and prestressed first.

Procedure of the cantilever construction:

- placing concrete and prestressing of two stiffening girder blocks
- placing concrete of the arch rib
- primary tensioning of diagonal members
- placing concrete of the vertical column
- placing concrete of the third block of the stiffening girder
- secondary tensioning of the diagonal members

The diagonal members were tensioned two times as to adjust the stress of the arch rib and the stiffening girder.

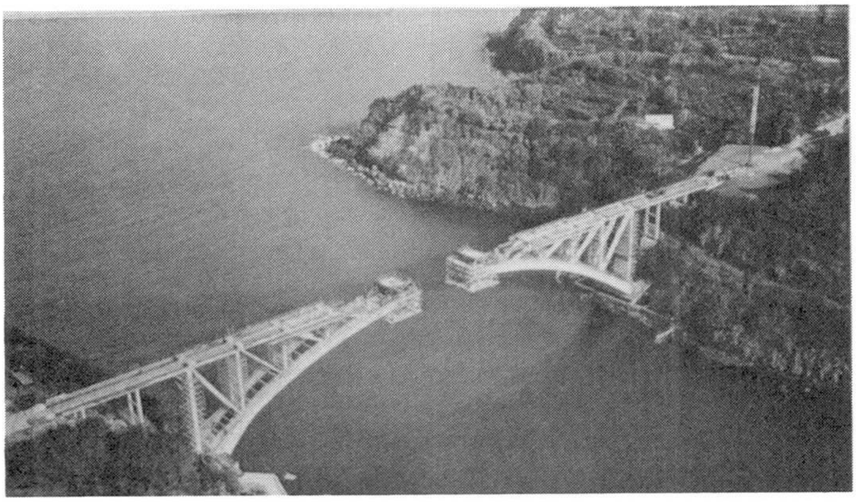


Fig. 2

Hokawazu Bridge under construction

Client:Saga Prefecture

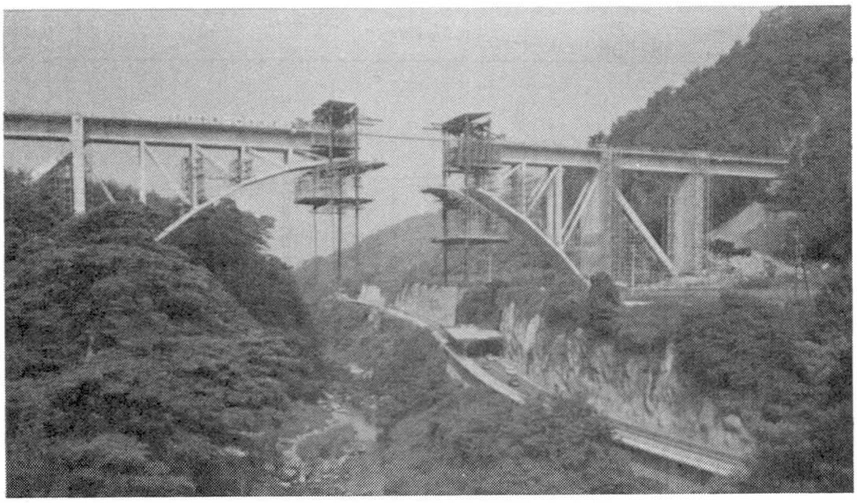


Fig. 3

Akayagawa Bridge under construction

Client:Japan National Railway

2.3 Usagawa Bridge

The 204m-arch-span Usagawa Bridge was completed with the pylon-Melan combined method in 1982. The bridge was constructed with a vorbauwagen, while the stay cables were installed from the pylon and tensioned during the construction of arch rib. Against the over turning moment the stay cables were anchored in the footing. With the progress of cantilever erection the over turning moment increases and the bending moment acts on the pylon column. Therefore the bending moment for the pylon column was reduced with the tension adjustment of both fore and back stay cables and the anchor cables. After about one fourth of the arch rib was constructed with the vorbauwagen, the remaining central part formed in a arch structure with preceding Melan materials was concreted with the vorbauwagen. The stress during the construction of the arch rib was reinforced by temporary prestressing, since the tensile stress increases in spite of tensioning the stay cables. These stay cables were removed after the closing of the arch rib. Then the stiffening girder was constructed by using girder formwork after erecting the vertical columns.

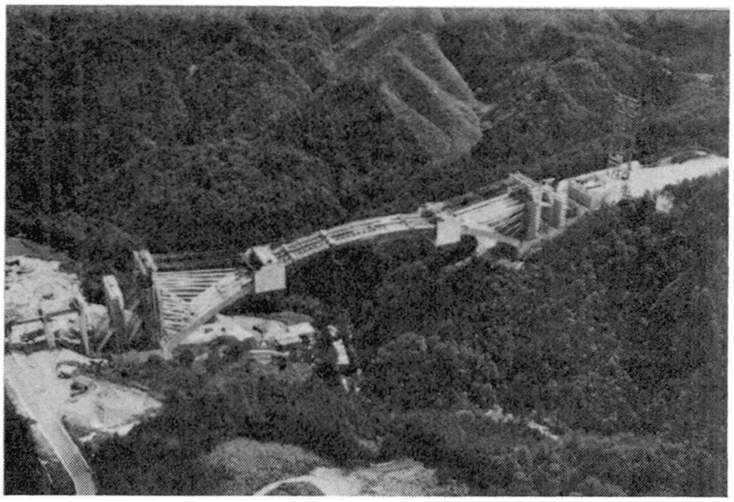
2.4 Beppu-Myouban Bridge

The 235m-arch-span Beppu-Myouban Bridge, the greatest concrete arch bridge in the Orient, was completed with the truss-Melan combined method in 1989. About two third part of the whole arch rib was constructed by the truss method, and the remaining center one-third was formed in an arch structure by using Melan material. For the backstay a concrete member was adopted similar to the Akayagawa Bridge. Temporary steel members were used as these horizontal and vertical members to form a truss structure with diagonal members during erection.

The backstay was prestressed three times with the increase of over turning moment. The diagonal members of prestressing bars were tensioned two times, so as to adjust the stress of the arch rib. The arch rib was also reinforced with temporary prestressing tendons.
Procedure of the cantilever erection:

- placing concrete of the arch rib
- secondary tensioning of the previously arranged diagonal members
- prestressing the arch rib
- installing the vertical, horizontal and diagonal members
- primary tensioning of the diagonal members

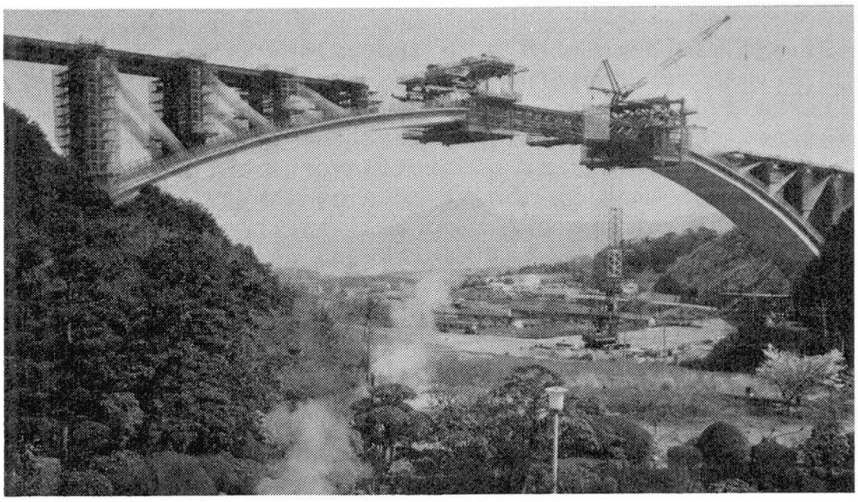
The central Melan was assembled on the ground and lifted up.
After closing the arch rib, the vertical members were concreted and the stiffening girder was constructed on the formwork of temporary H-beams used as horizontal members.



Client:Japan Highway Public Corporation

Fig. 4

Usagawa Bridge under construction



Client:Japan Highway Public Corporation

Fig. 5

Beppu-Myouban Bridge under construction

3.FUTURE DEVELOPMENT

Arch bridges have been constructed since ancient times. For the construction it is very important how erection members are used reasonably. On the basis of the experinces of these four bridges the followings may safely be said by the case of the concrete arch bridges in Japan.

• The truss method will be suitable for the bridges of about 150m-arch-span, while the pylon-Melan or truss-Melan method for the bridges more than 200m-arch-span.

• Concrete stay would increase the rigidity of the structure against the over turning moment during erection or earthquake, and it makes the prestressing control of stay easy.

• The stress of the arch rib or the stiffening girder can be adjusted with prestressing diagonal members. In the case of using the truss method the adjustments of about two times are necessary. Diagonal members using insulation can be controlled to the temperature-rise of 10^0C.

• The truss method can be combined with the construction of four members, such as arch rib, vertical columns, stiffening girder and diagonal members. In this case the use of temporary steel members could shorten the construction period.

• During the cantilever erection of the arch rib, prestressing in itself is necessary as external or internal tendons.