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Construction of the Yokohama Bay Bridge Superstructure

Construction de la superstructure du pont sur la baie de Yokohama

Erstellung des Brückenoberbaus für die Yokohama Bay Brücke

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SUMMARY

The Yokohama Bay Bridge is a huge cable-stayed bridge with the central span as long as 460 m, and its main girder is a double deck structure. At each step of construction actual values were checked by the design values, in order to assure safety·and precision. In particular, the construction of the central span was accomplished with high precision, owing to the introduction of the precision control system.

RESUME

Le pont sur la Baie de Yokohama est un pont haubané imposant dont la portée centrale est de 460 m. La poutre principale est une structure à double tablier. A chaque étape de la construction, des mesures ont été effectuées et comparées avec les calculs afin d'assurer la sécurité et la précision. Notamment, l'érection de la portée centrale a été réalisée avec une grande précision, grâce à l'introduction d'un système de contrôle.

ZUSAMMENFASSUNG

Die Yokohama Bay Brücke ist eine Schrägseilbrücke mit einer Mittelspannweite von 460 Metern. Der Hauptträger der Brücke ist zweigeschossig. Bei jeder Bauetappe wurden Messwerte abgenommen und mit den Vorgaben verglichen, um Genauigkeit und Sicherheit zu gewährleisten. Höchste Genauigkeit bei der Spannweite des Mittelteiles konnte durch die Einführung eines speziellen Kontrollsystems erzielt werden.

1. INTRODUCTION

The Yokohama Bay Bridge is a three-span continuous cable-stay bridge with a central span of 460 m and side spans of 200 m. (Fig 1.) It forms a section of the Bayside Line and was constructed at the position where it crosses the international fairway at the mouth of the Yokohama Port from Honmoku Wharf to Daikoku Wharf.

Its main girder is a double deck structure and the expressway on the upper deck began to be used in September 1989. The lower deck is to be constructed in the future except for those parts that have already been constructed as a minimum necessity. Its tower on the Daikoku Wharf side is provided with a lookout lounge and one can enjoy the view of the Yokohama Port from a height of 50 m above the sea and the promenade that leads to the lounge.

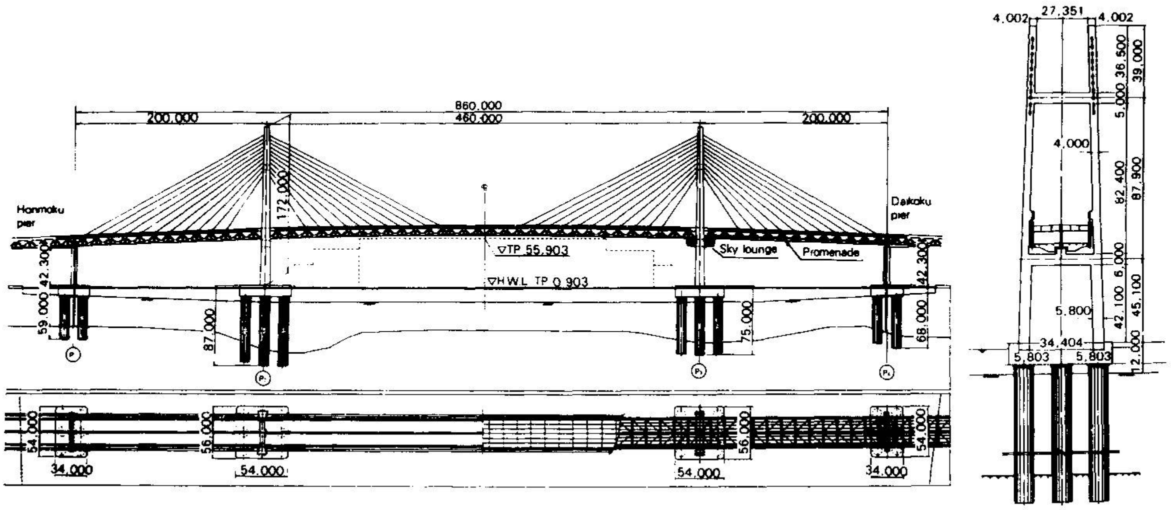


Fig. 1 General arrangement of the Yokohama Bay Bridge

This is the report about our construction method and outline of construction precision control, which was employed for the cantilever out erection of the main structure for the central span. This was done in order to successfully realize the design conditions of such a huge bridge as this.

2. CONSTRUCTION

This bridge was constructed in the following order:

1. the lower parts of the tower and the side piers were constructed as large blocks by means of a floating crane (FC).
2. The truss girders for the side spans were constructed as large blocks by means of an FC.
3. The middle parts of the tower were constructed as large blocks by means of an FC.
4. The upper parts of the tower were constructed by means of a crawler crane.
5. The truss girders and cables for the central span were cantilever out erected by means of a traveling crane.
6. Center section was connected.
7. To complete, the bridge surface was paved and the accessories were provided.

Aiming at high precision and fast construction, the truss girders for the side spans were constructed as large blocks by means of an FC, along with the lower half of the tower.

The main girder of the side span were constructed by a half-splits method with temporary bents at the center. Maximum weight of one block was 51,000 KN (c.f. Fig.2). The upper part of the tower was constructed by piling up a single block of about 980 KN, by means of the crawler crane of 6,370 KN capacity set on the main girder of the side span. (c.f. Fig.4)

Main structures of the central span were connected at the bridge center using diagonal cables and cantilever erected from both sides of the towers. (c.f. Fig.3)

At each step of construction, we first confirmed whether the deflection and strength of the trusses were as they had been assumed in the design calculation and then proceeded to the next step. Especially in constructing the truss girders and cables for the central span, we handled girder deflection, cable tension and tower inclination as precision control items and collected the design and measured values at each step of the cantilever construction, so as to find errors at the time of closing the central section and at the time of completion within the limits of the prescribed values and saw to it that adjustment could be made by the shim plate in the cable anchor if the results exceeded a prescribed value.

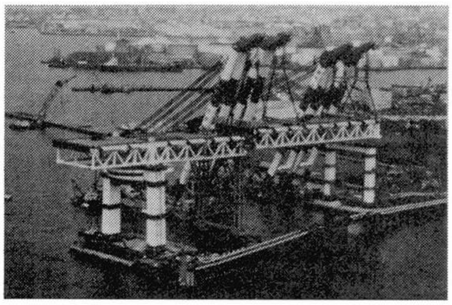


Fig.2 Construction of Side Span Main Truss by Large Block System

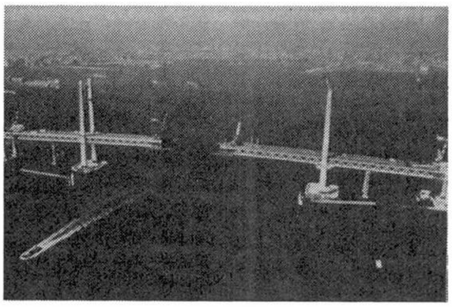


Fig.3 Cantilever Construction of the Central Span

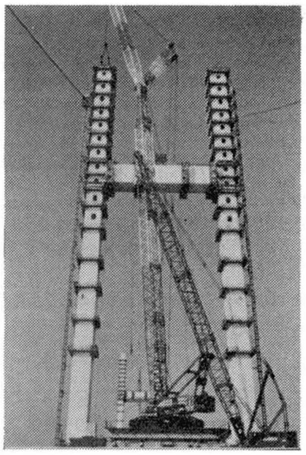


Fig.4 Tower Construction by Block System

3. PRECISION CONTROL AT THE CONSTRUCTION

In case of usual bridge construction, deviation of stress and dimensions from the design values are inevitable. However, in case of a cable stayed bridge like this, deviation can be adjusted to some degree, as the distance between fixed points can be changed by means of shim plates installed at fixed points on the cables.

On the other hand, prevention of errors by precision control at each step during construction is very important - adjustment of stress and dimensions after construction of the huge bridge like this is very difficult and too late.

In order to assure safety during construction and high precision at completion, we developed and applied at our construction the unique precision control system including special measuring at construction of the central span.

3.1 Control Items

Table - 1 shows precision control items and the range covered by shim adjustment. Concerning an item "direction of girder" in the table, some adjustment is possible by unbalancing the tension of the cables on two planes, however, torsion is produced in the main girder, the item should be considered only at closing time rather than designated as for the shim adjustment item.

Temperature of the bridge body is used for correction of measured temperature, and reaction force of the bents in the sea is to be used for assuring the adequacy of the calculation model.

3.2 Control Values for Error

As each error in cable tension, camber of main girder, and tower inclination belongs to a different quantity group, and in order to control these quantities as a whole, quantitative impact of each error should be understood, and an allowable range of error must be defined for effective shim adjustment work at the construction field.

For construction of this bridge, two values are set, one for a control limit for defining an allowable range, and the other for target control value.

In other words, the former is the maximum design value for errors at manufacturing and construction, and the latter is the standard value for shim adjustment work.

Table 1 Accuracy Control Items

Measuring Items	Control Items	Control Items by Shim Adjust.	Remark
Cable Tension	○	○	
Girder Camber	○	○	
Direction of Girder	○		Measurement by Transit
Tower Inclination	○	○	
Bridge Body Temperature			For Correction of Measurement
Reaction of Temporary Bents	○		For Confirmation

Table 2 Combination of loads and Increment of Allowable Stress

	Load Combination	Increment of Allowable Stress
Control Limit Value	D+L+T+SD+E	1.15 (Design Value)
Control Target Value	D+L+E	1.00

D : Dead Load
L : Live Load
T : Influence of Temperature Change
SD : Influence of Sinking Support Point
E : Influence of Error at Manufacturing and Construction

3.2.1 Cable Tension

The maximum allowable stress in the cable is controlled, considering the tension errors introduced at each step of construction and load combinations as listed in Table - 2.
Out of the load combinations used for the design of this bridge, the load combination employed for evaluation of control limit value of cable tension including errors is the one involving the influence of errors "E" at manufacturing and construction stage, and critical for the cable.

However, from the fact that a cross section area of the cable is calculated based on the assumption that stress from the load combination "D+L" is 90 - 95% of the allowable stress, load combination "D+L+E" with increment rate of 1.00 was defined as the control target value.

3.2.2 Camber of the Main Structure

Table - 3 shows control limit values and control target values of the main girder camber. As an influence of the absolute values of the girder camber on stress conditions is not remarkable, it was decided considering the size and construction method of this bridge.

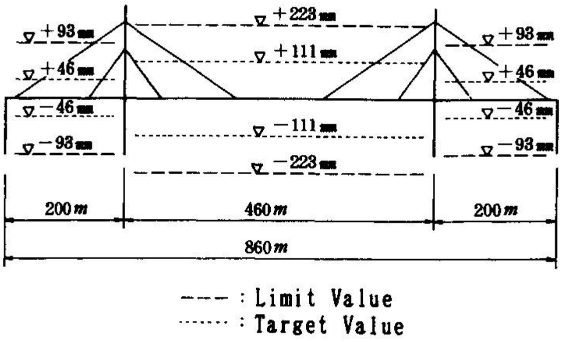
Vertical discrepancy between two main structures, Honmoku side and Daikoku side ones, was taken into consideration from the beginning of the design stage, and then, it is to be taken up as the standard of judgment after the latter half of the construction.

3.2.3 Tower Inclination in the Bridge Axis Direction

Tower inclination is controlled by means of horizontal movement of the tower top - control values are as listed in the Table - 4. The design value of the tower top movement is H/2,000=86 mm, and the target value was decided considering construction errors in it's free standing condition.

Table 3 Control Value of the Main Girder Camber

	Absolute value	Vertical Discrepancy of Girders for Connecting Center Blocks
Control Limit Value	δa = ±1/2:{25+(L−40)}	100 mm (Design Value)
Control Target Value	1/2 of the Control Limit Value	Same as the above Value
δa : Standard Limit Value (mm) L : Distance between Two Support Points (m)		



3.3 Control System and Control Flow

Since precision control and adjustment work had to be done in a brief period at night when the temperature stabilized, we developed an construction precision control system to handle computerized full-automatic measurement and data processing in constructing the bridge. (Fig.5, Fig.6)

Table 4 Control Value of Tower Inclination

	Horizontal Movement of Tower Top (mm)
Control Limit Value	H/2,000 = 86 (Design Value)
Control Target Value	H/5,000 = 34
H: Tower Height (m)	

Fig.7 shows the control flow diagram.

As a preparation in advance of the shim adjustment work, the calculation model is decided based on various errors and construction methods; control limit values and influence values of shim plate thickness and temperature on cable tension and deformation are evaluated by analytic calculation, which is processed by a computer.

On the day of shim adjustment work, construction loads (mainly those on the bridge surface) are to be surveyed, and the resultant load data will be input into the personal computers for precision control in the construction field linked with the large computer, and detail control calculation will be conducted.

After confirmation of night time temperatures at each part of the bridge being stabilized, primary measurement is to be conducted. Vibration frequency of the cable is measured by a cantilever displacement gauge which is attached, and the main girder camber by the level meter (communicating tube), tower inclination by the laser flood lamp, and temperature of framework member by a thermo couple. These measuring works are controlled by the centralized control system through personal computers (for measuring) in the construction field.

Conversion of the cable vibration frequency into tension, and temperature correction are processed by the computer. On the other hand, measured data are transmitted to precision control personal computers, which calculate out optional solutions for shim adjustment by the least square method, and expect values for any shim adjustment of free choice, according to input data and control values; the final shim value for actual use is decided in reference to these computer calculation results.

After shim adjustment work, if comparison of measured values and control values mentioned before give good results, the series of work for the day is finished, and the work on the next step will be started on the following day.

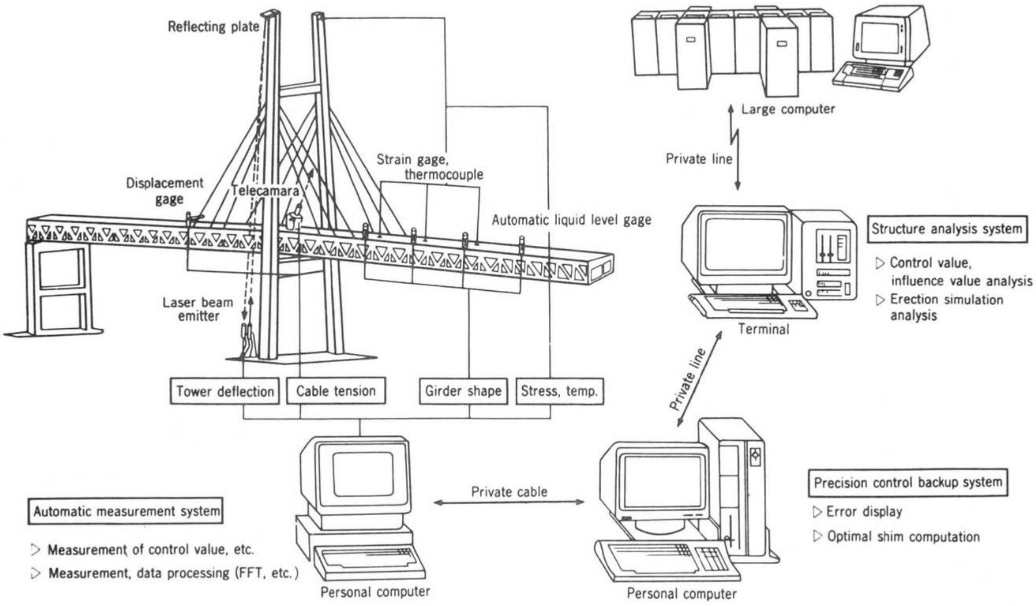


Fig 5. Schematic Diagram of Control System

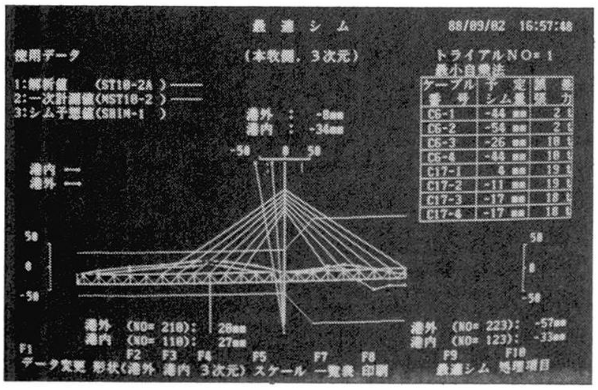


Fig. 6 Example of Display

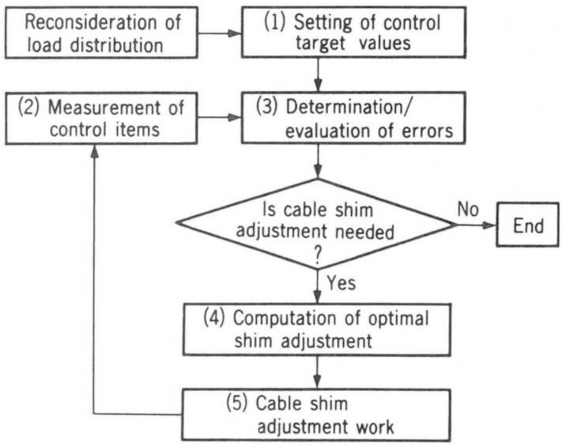


Fig. 7 Control FLow Diagram

4. CONCLUSION

In order to assure safety and high precision in construction of the large cable-stayed bridge, we have developed and applied the precision control system under construction to this bridge. This enabled us to close the central section easily and with hardly any errors. Furthermore, the shape and cable tension errors at the time of completion were so small that they were precisely within their prescribed limits then there was no need of shim plate readjustment.