Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte
Band: 71 (1994)

Artikel: Design of the France-Japan friendship monument
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DOI: https://doi.org/10.5169/seals-54136

Design of the France-Japan Friendship Monument

Projet du monument de l'amitié franco-japonaise

Entwurf des französisch-japanischen Freundschaftsdenkmals

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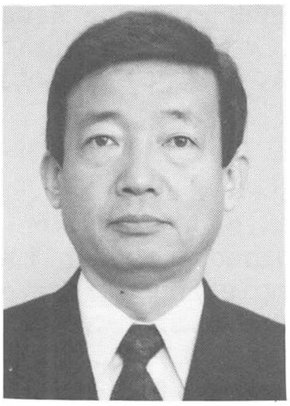

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SUMMARY

A project to construct a Monument as a symbol of friendship between France and Japan is under way in Japan, for completion in 1998. This paper describes the structural design by the Japanese side based on the concept design by French architect Patrick Berger. A 210 m-long, 21 m-width, and 4,2 m-high box-girder steel table, covered with thin bronze plates, will be supported at each end by a jungle-gym-like grid of steel pillars. Prestressed cables will be used to offset deflection caused by the bronze table's weight.

RÉSUMÉ

Un monument symbolisant l'amitié franco-japonaise est en construction au Japon et devrait être achevé en 1998. En se basant sur une conception de l'architecte français Patrick Berger, les ingénieurs japonais ont étudié la structure porteuse. Une poutre-caisson métallique de 210 m de long, 21 m de large et 4,2 m de haut, recouverte de minces plaques de bronze, est supportée à ses extrémités par un treillis complexe de montants métalliques. Des câbles de précontrainte sont utilisés pour compenser les déformations dues au poids des plaques de bronze.

ZUSAMMENFASSUNG

In Japan befindet sich ein Monument zur Symbolisierung der französisch-japanischen Freundschaft im Bau, das 1998 fertiggestellt sein soll. Ausgehend von einem Konzept des französischen Architekten Patrick Berger wurde von japanischer Seite das Tragwerk entworfen. Ein 210 m langer, 21 m breiter und 4.2 m hoher Stahlkasten-Träger, verkleidet mit dünnen Bronzeplatten, wird an beiden Enden von einem dschungelartigen Geflecht aus Stahlpfosten getragen. Vorspannkabel werden zum Ausgleich der Durchbiegungen infolge des Gewichts der Bronzeplatten eingesetzt.

1. OUTLINE OF THE MONUMENT PROJECT

1.1 Background

The Statue of Liberty, symbolizing liberty which was considered as a theme for the mankind in the 20th century, was constructed in the New York Bay as a token of friendship between the United States and France about 100 years ago in 1886. In line with this spirit, the French-Japanese Symbol Association was founded in 1986 aiming at pursuing a joint project for constructing a communication monument, as a symbol of exchange and communication on global scale, which would become indispensable for the global community in the 21st century in Japan, as a token of friendship between France and Japan towards the 21st century.
As a result of the design competition held twice in France, the " Awaji: Garden of Tropics " by French architect Patrick Berger was selected in July 1989.
The Japanese side set up the Japanese Committee for the Japan-France Friendship Monument in December 1989, in order to promote it as a project supported by the nation, for which purpose the Association of Intercultural Communication was set up in May 1993 as an organization entrusted with the construction of this monument, aiming at further promoting the project.

1.2 Progress of design work

The French side presented a conceptual design in January 1990, and the results of the preliminary basic design were presented to the Japanese side in two occasions in June 1990 and November 1992. As a result of technical discussion by both sides, the completion of the preliminary basic design was confirmed, and also that the Japanese side should tackle with the detail design and the construction of the monument by counting with the cooperation from the French side.
For this design, the construction technology study group (5 teams comprising 51 specialists from structural design, wind resistant design, seismic design, materials, and construction planning fields) and the specialist study group (led by Tsutomu Yamane, former President of Honshu - Shikoku Bridge Authority and comprising 15 members chosen from academic, governmental, and design fields) were set up inside the promoting organization on the Japanese side.
At present the Japanese side is working on the detail design, for which the basic design stage has almost been completed, and based on whose results this report is filed.
For the work schedule in the future, the detail design will be completed at the end of 1994 to start the construction of the monument. Completion of the monument is scheduled for the spring of 1998.

2. MONUMENT CONCEPT

2.1 Basic concept

Patrick Berger, who proposed the monument's scheme, aims at realizing a monument embodying the theme of "exchange - communication" as its basic concept. For this reason, the monument is structured to the image of a gate, serving as the starting point of communication.

2.2 Scale of monument and proposed site

The length of the bronze table is so designed as to be compatible with the height of the foundation of the monument (Fig. 1). Size of the element of the monument is :
 Bronze table (210 m long, 21 m wide, 4.2 m thick)
 A couple of twin pillars (50.4 m high, 8.0 m wide, 12.0 m deep)
The monument will be located on a spot where longitude 135 E, which marks the Japan Standard Time, passes; and, the construction site is located atop a small

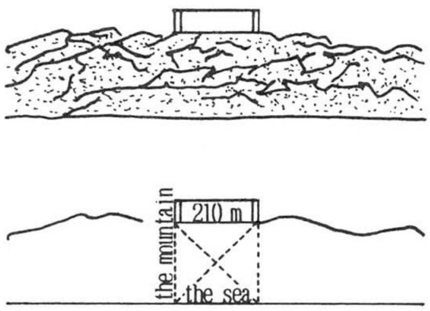

Fig.1 Setting of length and height of the monument

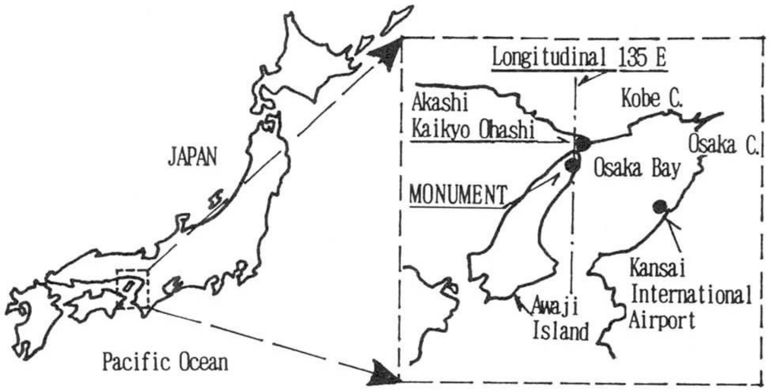

Fig.2 Location of the monument

hill bit higher than 200 m found at about 1.5 km from the coast, inside the Prefectural Awaji Island Park at the northern end of the Awaji Island. And, a superb view open to Osaka Bay will be enjoyed from the site (Fig. 2).

3. STRUCTURAL PRINCIPLE AND ERECTION METHOD

3.1 Structure of bronze table

3.1.1 Structural principle

The external form of the bronze table features an extremely slender structure as the depth of the table beam is 1/50 of its length in the axial direction; while for the transversal direction, it has a rectangular cross section of 1:5 ratio. The steel box-girder type is used to ensure sufficient bending stiffness and torsional stiffness, besides by taking into account the large span length; and, for the single-span steel box-girder style, this bronze table has the world's longest span length. Steel cables for prestressing ("PS cables") are parabolically arranged inside the cross section of the steel box-girder as shown in Fig. 3; thus, the structural principle is to offset the bending moment due to the dead weight of the table with the cancellation moment through the introduction of cable's tensile force, so as not to cause deflection. And high-tensile steel having tensile strength of 7.8 tf/ cm² materials are used.

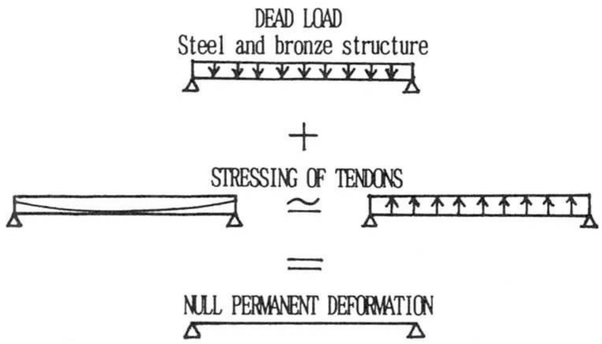

Fig.3 Structural principle of the monument

3.1.2 Structural experiments

Structural experiments were carried out by using 5 speciments(scale: about 1/10) (Fig.4)in order to verify the effect of cancellation moment of the steel box-girder compressed by PS cables, and also to confirm vibration properties of the beam due to the tensioning of PS cables (PS cable tensioning distance: about 17 m). As a result of this test,the cancellation moment effect could be confirmed in all speciments. The tests also revealed that the dynamic characteris-

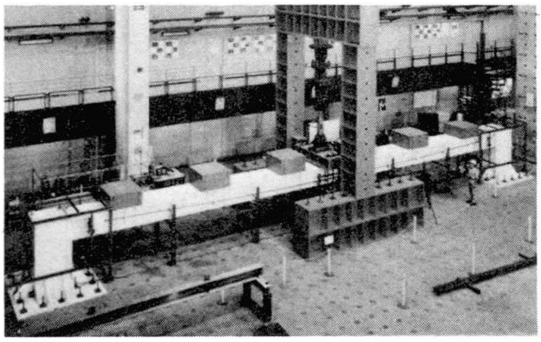

Fig.4 Structural experiments of the box-girder compressed by PS cables

tics of the PS teel beam did not depend on the compressive force of the steel beam caused by the tensioning of PS cables.

3.2 Pillar structure

3.2.1 Structural principle
The system truss structure by using tubular section is widely used in Japan for the roof structure of gymnasiums and assembly halls. The pillar (Fig.5) of the monument is used as a perpendicular support member to sustain the weight of the bronze table,large cross section of the member is required. Also from viewpoint of design, square steel member with solid cross section(150 mm x 150 mm)is used in order to realize a compact cross-sectional area. This cross-sectional form presents a regular square, which is threaded at both ends. A hexagonal sleeve is used at the threaded part to avoid fatigue failure; and, joining is achieved by introducing the compressive force to the sleeve and the tensile force to the threaded part, thus minimizing the alternation of stress at the threaded part.

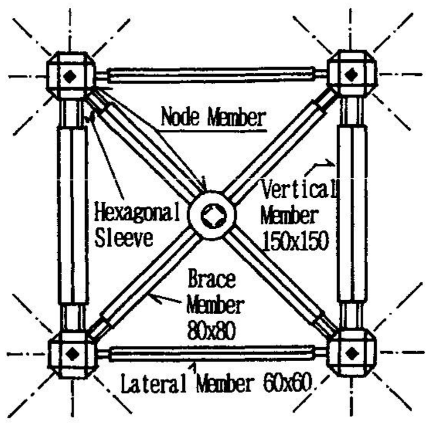

Fig.5 A unit frame of the pillar

3.2.2 Structural experiments
We conducted the manufacturing test and mechanical tests with the structural members, and we also carried out a test for confirming the axial force introduction method by hexagonal sleeve, and the load bearing test.

3.3 Erection method

3.3.1 Lift-up method (Fig. 6)
The bronze table work will be carried out in the following way:
- Pillar materials and bronze table materials will be manufactured at shop. The bronze table materials will be produced by block unit at the shop, and will be carried to the construction site.
- Pillars will be assembled on the base, whose work would have started earlier at the site. The central part of the bronze table will be manufactured at the site as an integral structure on the ground right beneath the proposed place of the table; and, up to the tensioning of cables will be completed.
- The end part of the bronze table will be assembled to the top of the pillar.
- The bronze table assembled on the ground will be elevated and will be joined with the blacket of the bronze table, which is set to the top of the pillars, by using high-strength bolts ("HT bolts").

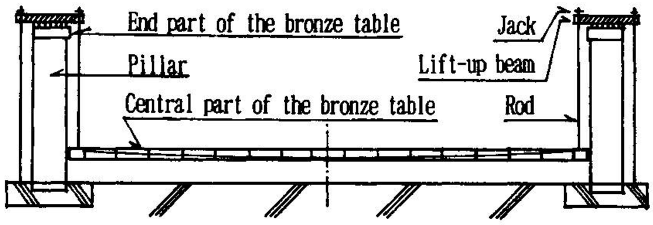

Fig.6 Lift-up method

3.3.2 Joining method
The bronze table should, in principle, be joined by welding before the lifting up. The joining of the bronze table following the lifting up will be made by using HT bolts.

4. DESIGN PRINCIPLES

4.1 Load

The bronze table was designed to the total weight of 5,100 tf, comprising 4,000 tf of steel members, 500 tf of PS cable members, and 600 tf of bronze (21.0 tf/m at the center part of the bronze table). The weight of the pillar is 4,700 tf in total, comprising 3,600 tf of steel members and 1,100 tf of glass. Thus, the total load of the entire monument structure is 9,800 tf.

4.2 Seismic design

Japan is located on the Pan-Pacific Seismic Belt, thus is prone to earthquake, and has experienced a large number of earthquakes of huge scale in the past. For this reason, seismic design is considered as one of the most vital design elements regarding the design of buildings and civil engineering structures.

4.2.1 Seismic design method

The input seismic level used by the earthquake response analysis, which was used for the seismic design of the monument, was set forth as follows:

Level 1 earthquake: Presupposes moderate earthquake, which might possibly occur during the expected durable life of the monument. Maximum velocity of horizontal movement is 20 cm/sec.

Level 2 earthquake: Presupposes severe earthquake, which might occur at least once during the expected durable life of the monument. Maximum velocity of horizontal movement is 40 cm/sec.

And, the following design policy was set forth for the members to allow the use of this monument over a longer period of time as compared with ordinary structures.

Against Level 1 earthquake: The member's stress is to be below the short-term allowable stress.

Against Level 2 earthquake: The member's stress is to be within the elastic arange.

4.3 Wind resistant design

Due to geographic conditions, Japan is under the influence of the prevailing westerlies throughout the year, being the northwesterly seasonal wind prevailing in winter. Typhoons come close to or cross the Japanese archipelago from summer to autumn every year. Wind tunnel tests were conducted in order to grasp the wind-resisting features of the structure.

4.3.1 Wind resistant design method

The design wind velocity was set forth based on the guidline by Architectural Institute of Japan.

Level 1 wind velocity: 61.1 m/sec

Level 2 wind velocity: 68.1 m/sec

Against Level 1 wind velocity: The member's stress is to be below the short-term allowable stress.

Against Level 2 wind velocity: The member's stress is to be within the elastic range.

4.3.2 Design wind loads

Stress analysis was realized for each of the average wind load and the variable wind load, and the results from the both were added together in order to see the total stress. For the average wind load in this case, the coefficient of wind force of the bronze table and the pillar was set based on the results of the static vibration response test. For the variable wind load, the stress analysis was made by providing the displacement, which was sought from the results of the dynamic vibration response test.

4.3.3 Wind tunnel test and wind observation.

As the wind tunnel tests, we conducted the analysis of air flow at site, the site air flow reproduction test, static wind load (three-component force and six-component forces) test, average wind pressure and variable wind pressure measurement, and dynamic vibration response test(Fig. 7). It was found out for the monument that, if wind blows in a direction at a right angle to the bronze table, wind resonance of the bronze table was caused, but destructive vibrations (flattering or galloping) were not caused, and also that such resonance was hard to be generated in the turbulence, but the irregular vibration (buffeting) due to the breathing of wind was prominently caused in the turbulence. An observation tower (70 m tall) was installed at the site, and the wind observation was realized since July of 1992. These wind observation data were reflected in the detail design as basic data for setting forth the design wind speed.

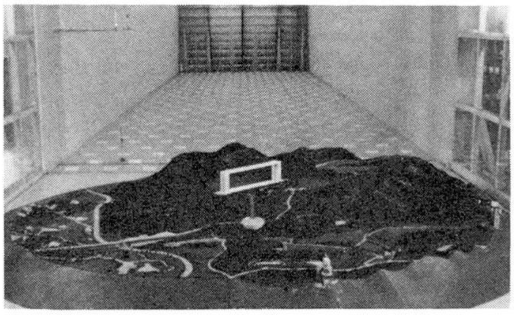

Fig.7 Wind tunnel test (monument and topographic model)

5. STRUCTURAL OUTLINE

A structural outline of the monument is shown below (Fig. 8).

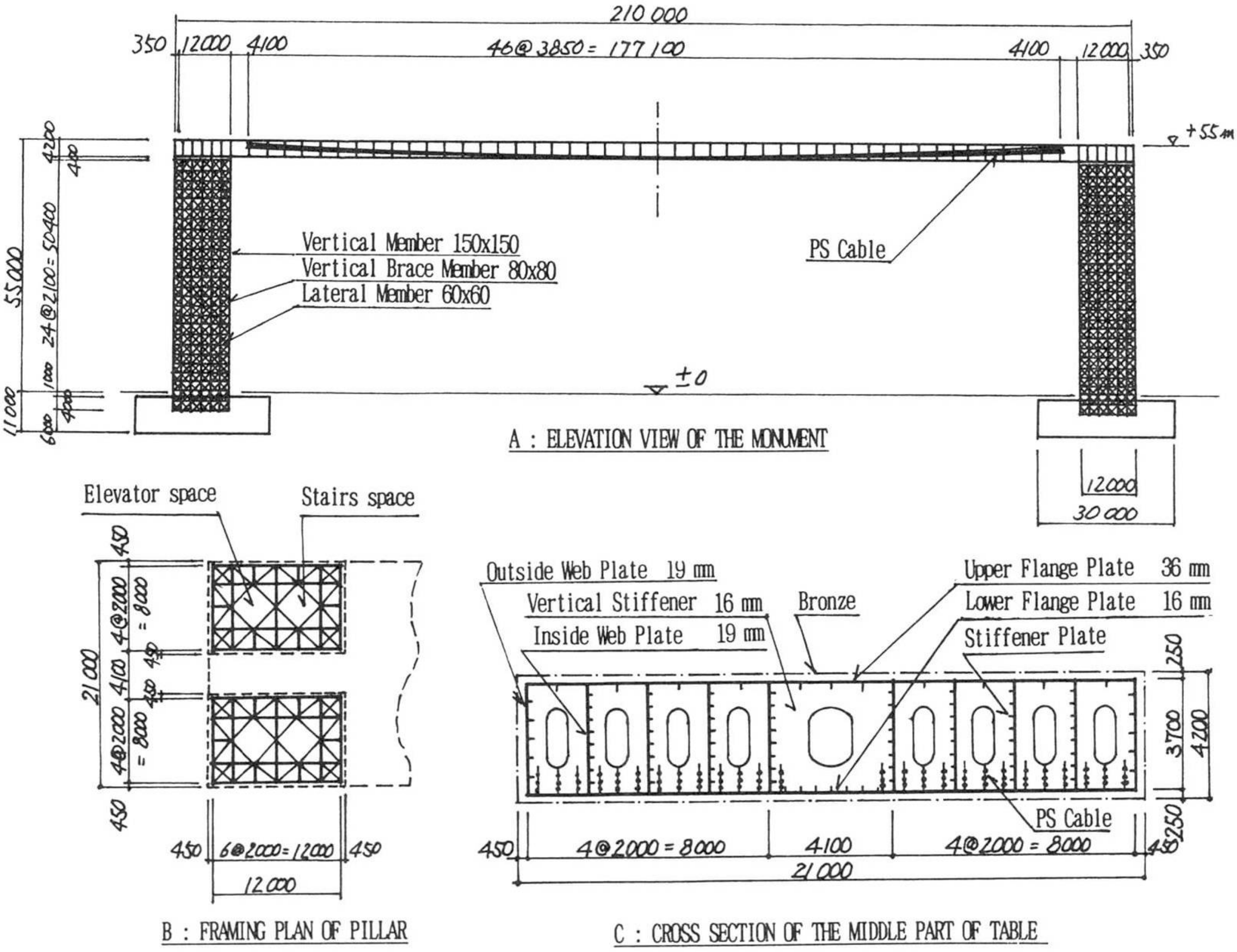

Fig. 8 Structural outline of the monument

6. AFTERWORD

The France-Japan Friendship Monument is now in the stage of detail design; and, the above outlines the studies, surveys and design works so far conducted. In addition to those, strength and fatigue tests of pillar materials and the study of flow of forces at the joint between the bronze table and the pillars are currently under way. And, observation of wind and seismic movements at site are also continuously carried out.