Suspension Bridge by Slant Hanger Cable
— Sagimai Bridge —

斜吊構造を採用した吊橋
— 鷺舞橋 —

 *
 **
 ***
 ****

* Ken OUE: Kawada Construction Co., Ltd.
大植　健：川田建設（株）
** Hirayoshi IMAI, P.E.Jp: Kawada Construction Co., Ltd.
今井　平佳，技術士（総合技術監理部門，建設部門）：川田建設（株）
*** Hideaki OHSIMA: Kawada Construction Co., Ltd.
大嶋　秀明：川田建設（株）
**** Hidekazu NOGUCHI: Kawada Construction Co., Ltd.
野口　秀一：川田建設（株）
Contact: hirayoshi_imai@kawadaken.co.jp

Keywords: suspension bridge, diagonal hanging, curved girder, construction steps
DOI: 10.11474/JPCI.NR.2014.105

Synopsis
This paper reports the remarkable points of the structure and construction method about a suspension bridge named Sagimai Bridge located in Fujisawa City, Kanagawa Prefecture, Japan. The whole view of the completed bridge is shown in **Fig.1**.
This suspension bridge is a continuous girder built with pre-stressed concrete, which is 129m in length, 4m in effective width, and 0.65m in height of the girder.
The girder of this bridge is curved and lifted up toward the diagonal direction of the girder's cross section with the hanging wires and main wires supported by the slanting tower.
While there had been some unusual bridges of this kind with such a unique supporting system in the world, this was the first achievement in Japan.
Under this kind of structural system, curved pedestrian deck must resist horizontal bending moment and torsional moment from the slanting hanging wires tying the deck and main cable.
Those out-of-plane stress resultants are offset by pre-stressing of the girder and post-slide of the intermediate support.
To control the stress from those moments without any over-stress causing cracks, etc. on the pedestrian deck, some additional construction steps had to be taken.
This report introduces the unique features of the Sagimai Bridge with a focus on the examinations of construction steps and construction management.

Fig.1 Whole view

Structural Data
Structure: 2-span continuous suspension bridge
Bridge Length: 129.0m
Span: 63.7m + 63.7m
Width: 4.0m
Tower Height: 21.330m
Owner: Kanagawa Prefecture
Designer: Kawada Construction Co., Ltd.
Contractor: Kawada Construction Co., Ltd.
Construction Period: Aug. 2007 – Jan. 2009
Location: Fujisawa City, Kanagawa Prefecture, Japan

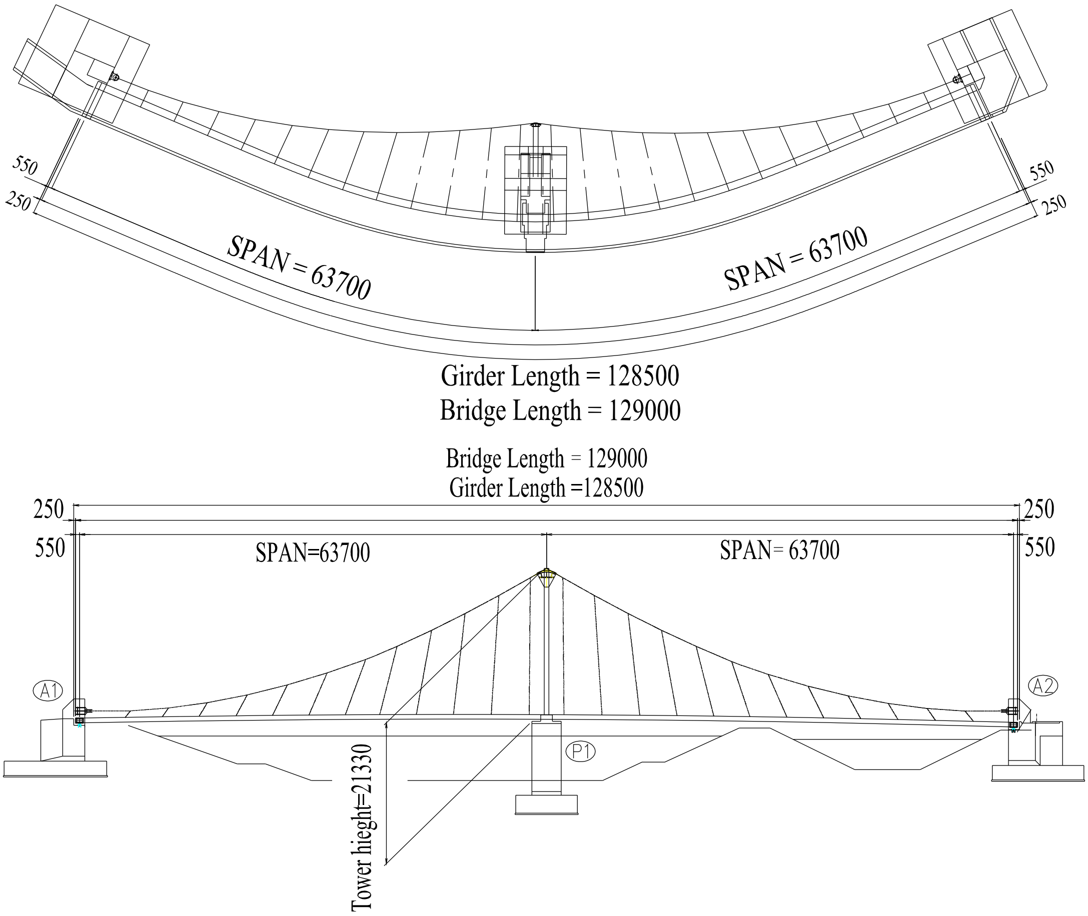


Fig.2 Plane view and side view

1. Introduction

Sagimai Bridge is a continuous girder bridge built with pre-stressed concrete, which is 129m in length, 4m in width, and 0.65m in height of the girder.

The girder is curved as a bow, suspended by 24 hanging wires from the main cable as shown in **Fig.2**. The main cable, suspended by the tower located beside the girder and slanting toward the opposite side of the girder, is anchored to the anchorages located at the both ends of the bridge. As there are different axis lines between the girder and the main cable, the hanging wires suspending the girder from the main cable are inclined between the cable and girder and not vertical as standard suspension bridges.

Then, the balance between suspending systems and weight of the girder must be kept during every construction step.

2. Introduction of design

(1) Maintenance of balance of the bridge

Since there are different axis lines between the girder and the main cable, the hanging wires suspending the girder from the main cable are not vertical as standard suspension bridges. First, on the design, the torsional moment caused by the tension of the hanging wires can be divided into two different torsional moments caused by the respective axis, vertical or horizontal component of the tension.

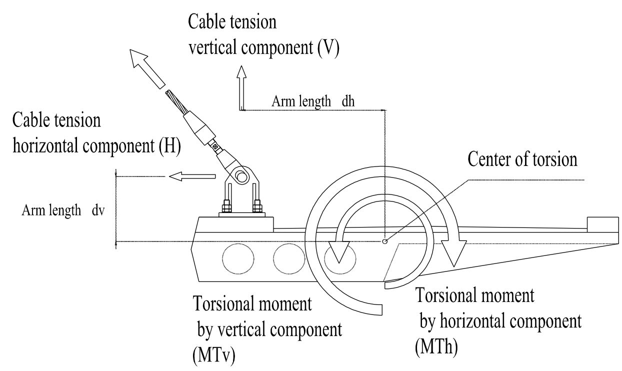


Fig.3 Concept of torsional moment concept

- Torsional moment by the tension of the vertical component: MTv = V × dh
- Torsional moment by the tension of the horizontal component: MTh = H × d

If the sum of those torsional moments is zero, the balance between the girder weight and the tension of hanging wires are maintained. The height of the anchor brackets for hanging wires were optimized to keep the balance. (**Fig.3**)

(2) Control of horizontal bending moment on the girder

On the design stage, considerable time was spent to

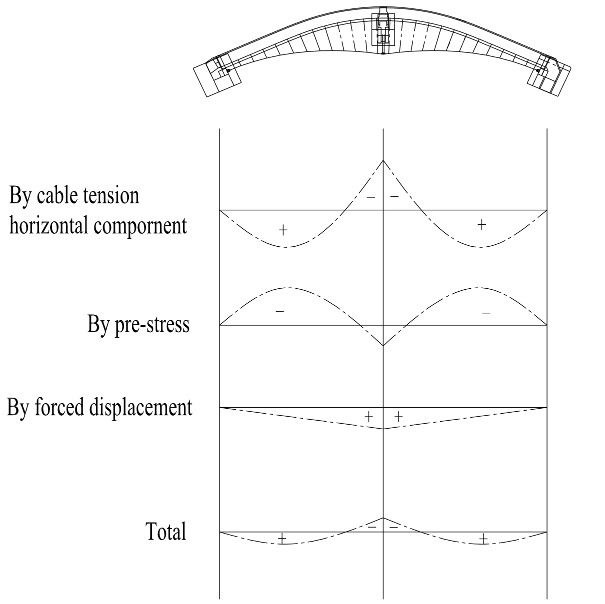


Fig.4 Concept of horizontal bending moment concept

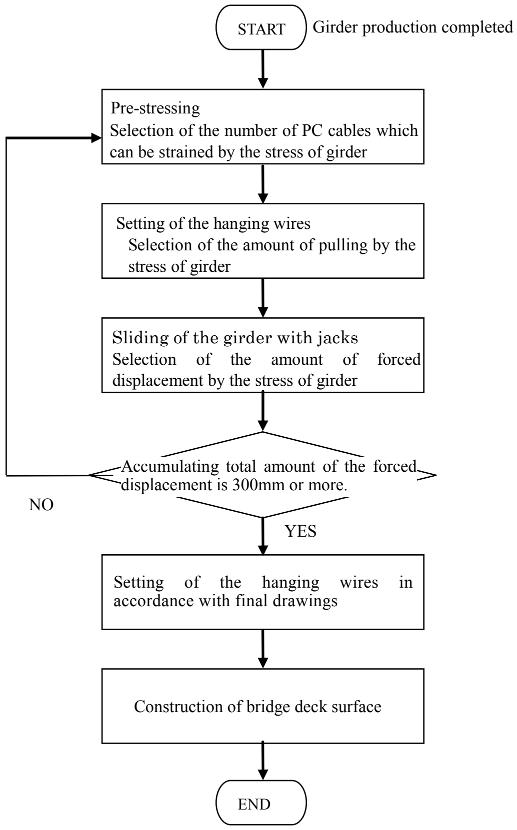


Fig.5 Flow of construction steps

study how to control the horizontal bending moment on the girder caused by the horizontal forces due to the tension of hanging wires. First, the forced displacement method was implemented in the construction stage. The procedure of the forced displacement method is as follows:

1. Set a jack on a middle support beside the girder, and
2. Push and slide the girder 300mm toward the main tower.

However, the counter bending moment by this method was not enough to control the horizontal bending moment caused by the tension of hanging wires.
Then, additional study was conducted to figure out how to arrange the pre-stressing steel wires to the locations in the girder where the forced displacement method would not give the counter bending moment. The result of this study was shown in **Fig.4**.

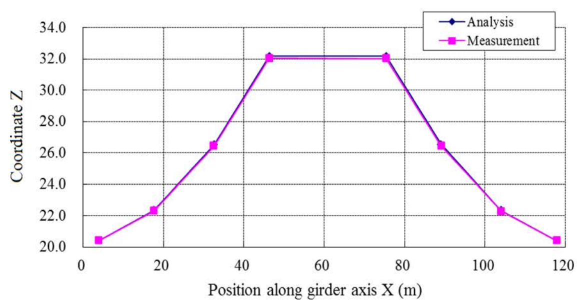
3. Construction

(1) Examination of the construction steps

The most important study was to decide the construction steps. In the construction stage, there are three main works; setting of the hanging wires, pre-stressing of the girder, and implementation of the forced displacement method. Each work can not be done at once since if it was done in that manner, the horizontal bending moment on the girder would be out of allowable bending moment. Therefore, those works had to be divided into several events and incorporated into the construction steps as shown in **Fig.5**.

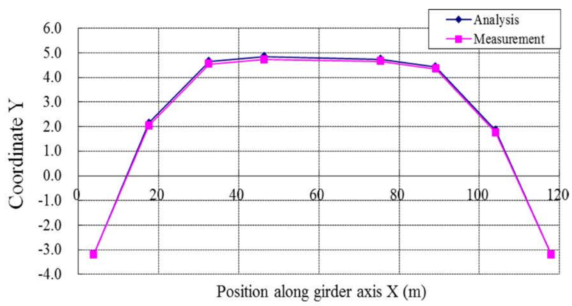
(2) Setting of the hanging wires

On the suspension bridge, when one of the hanging wires suspended from the main cable is pulled, the other hanging wires change their tension force and length, and the main cable also changes its shape and length to keep the balance between the hanging wires



a) Side view

Coordinate Z : Height from designated position, Z(m)



b) Plane view

Coordinate Y : Transverse distance from bridge axial line, Y(m)

Fig.6 Comparison of coordinate value of main cable between analysis and measurement

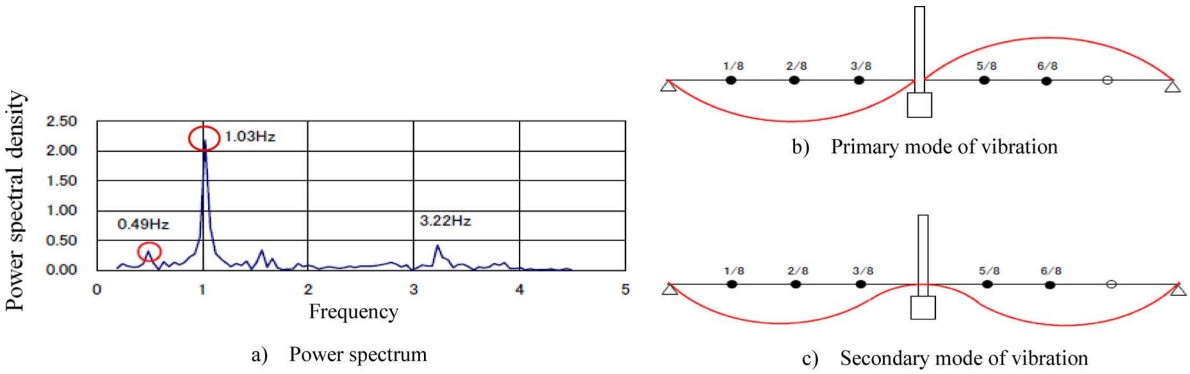


Fig.7 Measured natural period and mode of vibration

and the main cable.

There are two management methods for setting the hanging wires. One is to control the tension force of all wires at once. The other is to survey the coordinate value of the main cable at each point connected with the hanging wires and to compare the surveyed results to the designed values. Then, as the former method was considered to be impractical, the latter method was employed. **Fig.6** shows the result of management that most points surveyed were in good condition comparing with the designed spectrum.

(3) Verification of the proper period

In the design stage, the proper period of the bridge was planned so that it does not fall in a range between 1.5Hz and 2.3Hz. If the proper period falls in the said range, the pumping action caused by the walkers' stepping frequency may become uncomfortable and in the end may lead to a resonance and even cause other severe problems on the bridge. After the completion of bridge construction, the proper period of the bridge was measured and proved to be out of that range on each mode. According to the result of measurement, the natural period was 0.49Hz on the primary mode and 1.03Hz on the secondary mode. Therefore, it was confirmed that the natural period of the bridge settled in the proper and safe range. (**Fig.7**)

4. Conclusion

In this paper, the authors reported the several remarkable points of the structure and conducted examinations in the construction stage of Sagimai Bridge.

The name of the bridge "Sagimai" means a snow heron taking off out of the waterside with her widespread wings, the scene of which we can see everywhere in the park near the bridge. (**Fig.8**) This Bridge was opened to public in December 2009 and has now become a notable sight where a lot of people visit and enjoy their recreation with cycling, bird watching, and etc.

Finally, the authors wish to express our gratitude to all of the interested members who gave great advices throughout the design and construction period of this bridge.

Fig.8 Completed Sagimai Bridge

概　要

本橋は国内初となる片面吊り構造を採用したPC吊り橋であり，平面曲率が大きく斜め吊りされた補剛桁には，ねじりモーメントおよび面外方向曲げモーメントが大きく発生する構造となる。曲線桁によるねじりモーメントは斜めケーブルによる相反するねじりモーメントを発生させることでこれを低減させ，面外方向曲げモーメントに対しては，中間支点をポストスライドさせることで，面外モーメントの低減を図り，桁高を低く断面をコンパクト（桁幅2.5m）にしています。

また，施工に当たっては，中間支点部の強制変位・ハンガーケーブルの引き込み・プレストレスの導入により補剛桁に発生する断面力が変化していくため，それらを分割して与える施工ステップを検討し施工を行い，安全性と品質を確保した施工を行いました。