Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 52 (1986)

Artikel: Vibration test of Ohnaruto bridge to confirm wind-proofness

Autor: Okauchi, I. / Tanaka, A. / Iwaya, K.

DOI: https://doi.org/10.5169/seals-40344

VIBRATION TEST OF OHNARUTO BRIDGE TO CONFIRM WINDPROOFNESS

Honshu-Shikoku Bridge Authority

OUTLINE OF OHNARUTO BRIDGE

Ohnaruto Br.(Fig.-1) is a suspension bridge with the main span and total length of 876m and 1629m. The bridge is a highway-railway combined bridge with double-deck structure (Fig.-2), but it has been temporarily put into service for only highway since June, 1985.

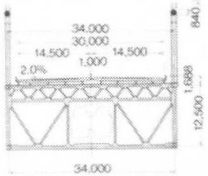


Fig.-2 Stiffening Truss Cross-section

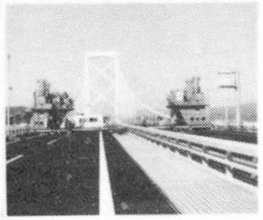
Fig.-1 Profile of Ohnaruto Bridge

WIND-PROOF DESIGN OF OHNARUTO BRIDGE

In the Honshu-Shikoku Bridge Standard for Wind-proof Design, a bridge is to be designed against the design wind speed (V_D), which is derived from the basic wind speed V_{10} (10 minutes average speed at 10m above the sea level) and the height and scale of the structure. V_{10} is expected to have the return period of 150years. Since Ohnaruto Br. is constructed in one of the most windy spots in Japan, V_{10} is determined 50m/s. So, V_D for the suspended structure, for example, is set as 73.0m/s. In addition, the design standard requires wind tunnel test to confirm whether the scheme which is statically designed against V_D have sufficient aerodynamic stability. The logarithmic structural damping for this wind tunnel test was determined by reference to a few previous measurements of long span suspension bridges under small amplitude oscillation or of small or medium span suspension bridges ; namely the decrement for an entire suspension bridge with stiffening truss has been set as 0.03.

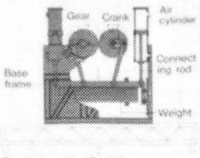
VIBRATION TEST OF OHNARUTO BRIDGE

Vibration test was planned mainly to assure the aerodynamic stability of Ohnaruto Br. by observing the oscillatory characteristics such as decrement, mode etc. at large amplitude similar to the reference amplitude (at which the decrement for wind tunnel test shall be fixed, namely 0.5 deg. for the torsional mode). To vibrate the actual bridge to such large amplitude, vibrators (Fig.-3) capable of producing large oscillatory force even at low frequency were developed and assembled. The oscillation of the suspended structure was observed mainly by accelerometers.



Vibrators at middle span

As the results, the followings were concluded. (1) The observed damping at large amplitude of the first symmetrical torsional mode during the free oscillation was 0.033, slightly higher than 0.03 which was specified in the design standard. The observed damping of the other modes was also higher, thus the damping used in wind tunnel test was concluded to be appropriate (Fig.-4,5 & 6). (2) The observed natural frequency for all test modes was also slightly higher than the calculated value, thus the frequency used in wind tunnel test was concluded to be appropriate, too (Fig.-7 and Tab.-1). From the above mentioned results, the quality of the wind-proofness of Ohnaruto Br. was assured.



Total weight	[illegible]
Dimension	[illegible]
Weight of weight	[illegible]
Weight stroke	[illegible]
Vibrating frequency	[illegible]
Vibrating wave shape	[illegible]
Vibrating force	[illegible]
Power	[illegible]

Fig.-3 Vibrator

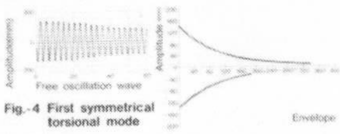


Fig.-4 First symmetrical torsional mode

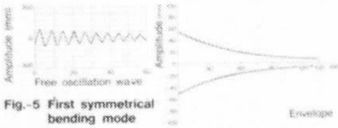


Fig.-5 First symmetrical bending mode

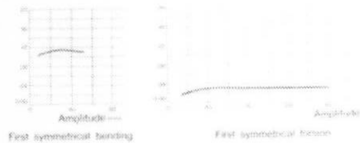


Fig.-6 Logarithmic decrement

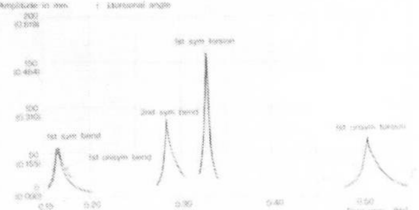


Fig.-7 Resonance curve

Mode	Natural frequency (Hz) Observed		Calculated	Ratio	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Tab-1 Comparison of natural frequency

Vibration Test of Ohnaruto Bridge to Confirm Wind-Proofness

I. OKAUCHI
Professor, Chuo University
Japan

A. TANAKA
Honshu-Shikoku Bridge Authority
Japan

K. IWAYA
Honshu-Shikoku Bridge Authority
Japan

N. FURUYA
Honshu-Shikoku Bridge Authority
Japan

1. Introduction

These experiments were significant such that two essential parameters for the windproof design by wind tunnels of large suspension bridges (decrement, natural frequency), were verified by applying large amplitude vibrations to an actual long span bridge (Ohnaruto Bridge). A summary of this report has already been described in the photo to be shown in the latter part. However, we feel that there may be places where the contents are indecipherable, so we decided to present the results again with some supplemental explanation.

Also, a flowchart of the windproof design of the Honshu-Shikoku Bridges, intensity of wind, magnitude of amplitude, and comparison table of decrement by mode of vibration, are newly added.

2. Windproof design of the Honshu-Shikoku Bridges

In the windproof design of the Honshu-Shikoku Bridges, the cross section obtained by the static design through the process shown in Fig.-2 must be verified dynamically using a wind tunnel test. The structural decrement to be used in this dynamic verification was determined with reference to actually measured examples of existing suspension bridges by means of small amplitudes. For the dynamic verification of a suspension bridge having a stiffening truss, the logarithmic decrement was assumed to be $\delta = 0.03$, and the cross-section was selected so as not to cause a flutter of larger than 1^{o} of single amplitude up to the wind velocity of 1.2 V_D (1.2 x design velocity) in a uniform wind flow.

3. Vibration experiments an Ohnaruto Bridge.

The experiments were performed for the purpose of verifying the total design rigidity of the suspension bridge by measuring the structural decrement provided for in the "windproof design standards" of the Honshu-Shikoku Bridges as mentioned earlier using a large amplitude near the standard amplitude (torsional angle of 0.5^{o}, single amplitude of about 15 cm) and by verifying the adequacy of the decrement and the frequency of vibration.

To achieve the purpose of these experiments, it was necessary to develop large scale vibrators for low frequency use. The mechanism and various data of the vibrators are shown in Fig-3.

To obtain vibrations of symmetrical and asymmetrical modes, the experiments were performed by placing the vibrator at the 1/2 point and 1/4 points of the center span, and the vibration behaviors of the girder were mainly measured by an accelerograph.

The vibration experiments were performed on the constant micromotion due to wind and on the forced oscillation and free vibration by means of the vibrator. Figs.-4 ~ 7 and Tables-1 ~ 2 show the results thereof.

From the results of the vibration experiments the following were verified:

(1) By comparing the results of the decrement obtained using three different methods, the value obtained during a large amplitude free vibration was largest. It can be seen that the decrement during the free vibration of the amplitude of about 2.0 cm or less tended to decrease but seemed to be constant above this amplitude.

The decrement of the first symmetrical torsional large amplitude free vibration was found to be 0.033, slightly exceeding the decrement of 0.03 for the wind tunnel test as provided for in the "windproof design standards". It was also found to exceed it in the other modes. Therefore, it is judged that the assumption made in the wind tunnel test was adequate for the decrement.

(2) As for the natural frequency, the comparison of the actually measured values and the calculated values is approximately the same, the actually measured values exceeding the calculated values in all vibration modes. Therefore, it is also judged that the assumption made in the case of the wind tunnel test was adequate for the natural frequency.

From the above it can be judged that the reliability of the results of the wind tunnel test performed on the Ohnaruto Bridge has been increased.

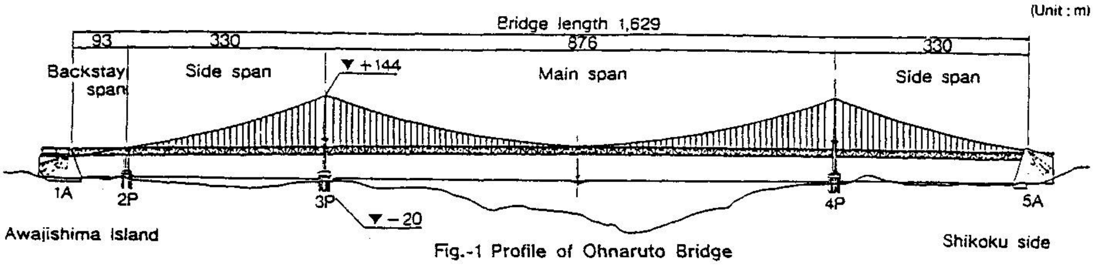


Fig.-1 Profile of Ohnaruto Bridge

Mode		Natural frequency (Hz): Observed ①: Micro-tremor	Natural frequency (Hz): Observed ①: Forced Osci.	Natural frequency (Hz): Calculated ②	Ratio ①/②: Micro-tremor	Ratio ①/②: Forced Osci.
Bending	1st sym	0.173	0.166	0.154	1.12	1.08
	2nd sym	0.298	0.284	0.268	1.11	1.06
	1st unsym	0.172	0.167	0.149	1.15	1.10
Torsion	1st sym	0.334	0.328	0.306	1.09	1.07
	1st unsym	0.527	0.506	0.497	1.06	1.03

Tab-1 Comparison of natural frequency

Method of experiment / Vibration mode	Constant micromotion: Weak wind (V = 7 m/s, SW)	Constant micromotion: Strong wind (V = 16 m/s, S)	Forced oscillation	Free Vibration: small amplitude smaller than 0.3 - 0.5 cm	Free Vibration: large amplitude larger than 2 cm
First symmetrical bending mode	0.075	0.078	0.097	0.086	0.112
Second symmetrical bending mode	-	-	0.064	0.063	0.080
First anti-symmetrical bending mode	-	-	-	0.082	0.109
First symmetrical torsinal mode	0.025	0.023	0.031	0.018	0.033
First anti-symmetrical torsional mode	0.027	0.025	0.040	0.045	0.057

Table-2 Comparison of Decrement

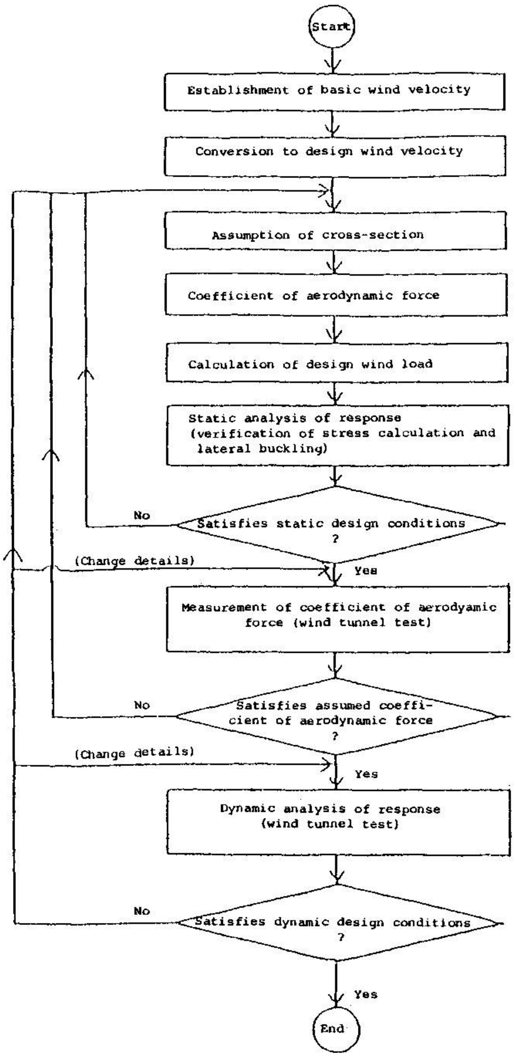
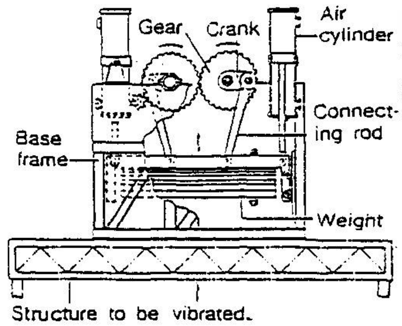


Fig-2 Flowchart of Windproof Design of Ohnaruto Bridge



Total weight	Appro. 90 ton/set
Dimension	H=6.30m W=6.10m L=7.10m
Weight of weight	33 ton
Weight stroke	±0.50 m
Vibrating frequency	0.1 Hz～0.6 Hz
Vibrating wave shape	Appro. sine curve
Vibrating force	Max. 196 N (0.5 Hz)
Power	Commercial electricity 440 V, 60 Hz

Fig. 3 Vibrator

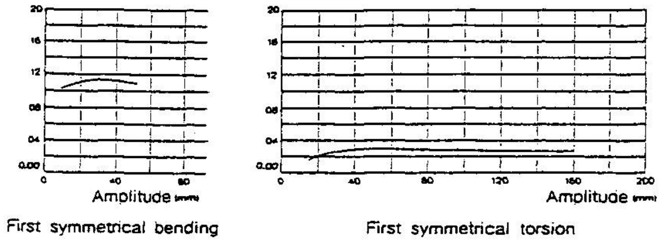


Fig.-4 Logarithmic decrement

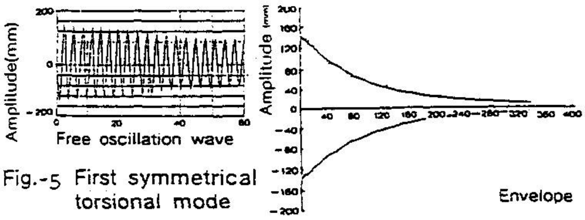


Fig.-5 First symmetrical torsional mode

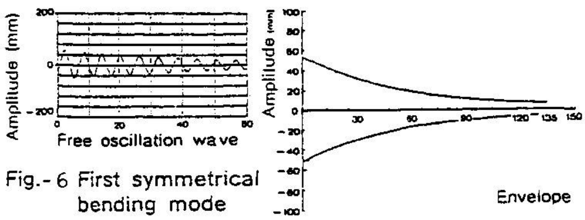


Fig.-6 First symmetrical bending mode

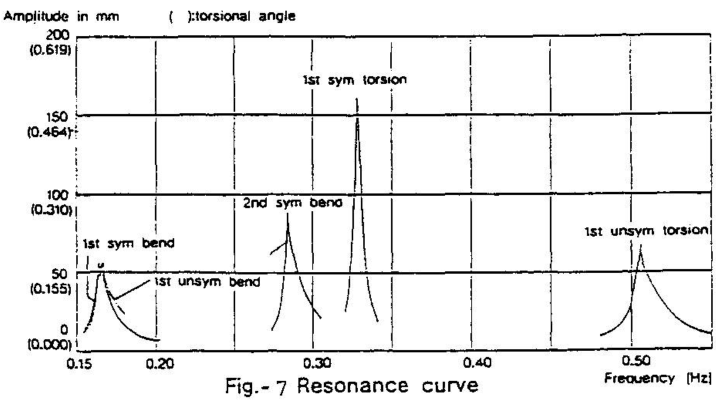


Fig.-7 Resonance curve