**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

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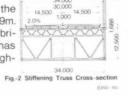


Honshu-Shikoku Bridge Authority

# VIBRATION TEST OF OHNARUTO BRIDGE TO CONFIRM WINDPROOFNESS

#### **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.





#### 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 (Vo), which is derived from the basic wind speed Vio (10 minutes average speed at 10m above the sea level) and the height and scale of the structure. Vio is expected to have the return period of 150years. Since Ohnaruto Br. is constructed in one of the most windy spots in Japan, Vio is determined 50m/s. So, Vo 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 Vo 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 ampli-

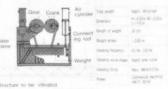


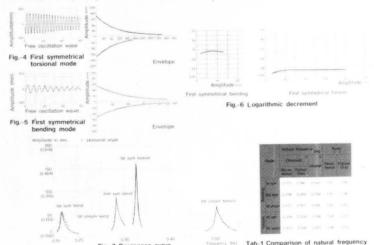
Fig.-3 Vibrator

tude 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.





# Vibration Test of Ohnaruto Bridge to Confirm Wind-Proofness

#### I. OKAUCHI

Professor, Chuo University Japan

#### K. IWAYA

Honshu-Shikoku Bridge Authority Japan

#### A. TANAKA

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  $^{10}$  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 0.50, 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  $\sim$  7 and Tables-1  $\sim$  2 show the results thereof.

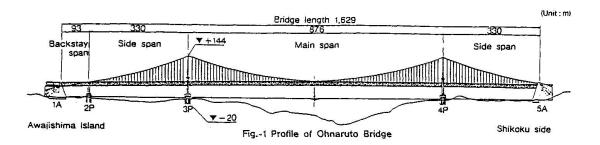
From the results of the vibration experiments the following were verified:

(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.



Made		Natura	i frequen	Ratio O/®		
		Observed		30	Micro-	Forced
_			Forced Osci.	Calculated	tremor	Oscı.
Bending	het sym	0.173	0.166	0.154	1.12	1.08
	2nd sym	0.298	0.284	0.258	1.11	1.06
	isi unayan	0.172	0.167	0.149	1.15	1.10
Torsion	lasi sym	0.334	0.328	0.306	1.09	1.07
	ist ungym	0.527	0.506	0.497	1.06	1.03

Method of experiment	Constant micromotion			Free Vibration	
Vibration mode	Weak wind (V = 7 m/s, SW)	Strong wind (V = 16 m/s. S)	Forced oscillation	smoll amplitude smaller than 0.3 - 0.5 cm	large amplitude larger than 2 cm
First symmetrical bending mode	0.075	0.078	0.097	0.046	0.112
Second symmetrical bending mode	-	-	0.064	0.063	0.080
First anti-symmetrical bending mode	-	•		0.082	0.109
Pirst symmetrical torsinal mode	0.025	0.023	0.031	0.018	0.033
Pirst anti-symmetrical torsional mode	0.027	0.025	0.040	0.045	0.057

Table-2 Comparison of Decrement

Tab-1 Comparison of natural frequency



