A long-term SHM to Satsunai Seiryu Bridge Considering Environmental Effect

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1. INTRODUCTION

Several decades after the booming of construction of bridges in Japan, it is expected that there will be a surge of aging problem for these bridges in the near future. Therefore, the promotion of an efficient, appropriate maintenance management technique is increasingly urgent. Ambient vibration based structural health monitoring (SHM) is widely accepted as one of the most promising and practical bridge evaluation methods nowadays. When applying a SHM process, it is important to guarantee the modal parameters be identified in a high accuracy. However, mode parameters are always affected by the changing environment, especially the influence of, temperature, wind, and other excitations.

In this study, a long-term remote monitoring is conducted on a cable-stayed bridge. The data acquired from the target bridge then applied to Natural Excitation Technique (NExT) and Eigensystem Realization Algorithm (ERA) therefore modal parameters are extracted. By analyzing the modal parameters, the characteristics and changes of them are identified. Based on three years' monitoring in this study, the relationship between modal parameters and temperature fluctuation along time history is investigated.

2. APPLICATION ON BRIDGE AND DATA PROCESSING METHOD

2.1 DESCRIPTION OF BRIDGE

The Satsunai Seiryu Bridge is a two span, cable-stayed bridge located in Hokkaido, Japan, which was open in 2002, as shown in Figure 1.There are 9 accelerometers, 4 clinometers and 2 thermometers installed in the pylon, girder and basement in order to record vibration data of the bridge, internal temperature and inclination of main tower. In this study, the data acquired from four excitation sources: ambient vibration, whose data have been recorded twice a day at 2:00am and 2:00 pm, wind, seismic, and traffic. The data from Nov.2004 to Dec.2007 are collected and analyzed.

2.2 RECORDS FROM EACH EXCITATION

Vibration data of Satsunai Seiryu Bridge from four excitation sources are acquired, and the feature of each excitation source was examined. Table 1 shows the vibration data numbers collected from Nov. 2004 to Dec. 2007. Some samples are eliminated because the data are recognized as unreliable, and some data were missed in 2007 because of error of the monitoring system. For ambient vibration data, the responses by wind and traffic load are always mixed with. However, for other excitation sources, the data are always assumed undisturbed.

2.3 APPLYING NExT AND ERA

In the proposed method of data processing in this project, NExT and ERA are applied [1]. Firstly, the NExT is used to calculate correlation function from vibration data. Assuming that the displacement, velocity and acceleration process are weakly stationary and the excitation is uncorrelated with the

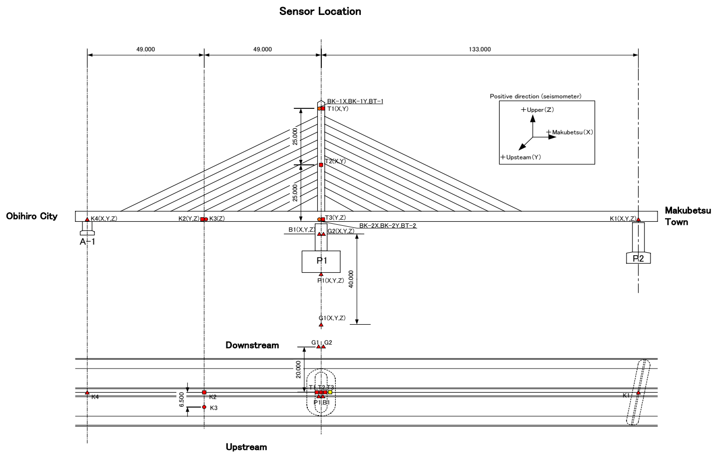

Fig. 1 Satsunai Seiryu Bridge

Table 1 Vibration data from Nov.2004 to Dec.

Excitation Sources	Sample Number
Seismic Observation	25
Vibration by wind load	136
Vibration by traffic load	128
Ambient vibration response	2778

force, it is recognized that the cross-correlation function of the responses of the structure with a reference signal satisfies the homogeneous equation of the motion. Therefore, the cross-correlation function can be treated as free response data.

The second step is the extraction of modal parameters from the correlation function using ERA. In the first step, Markov parameter is composed from impulse response gained from NExT. The column number of Markov parameter is decided by the number of input. There are 10 channels on the pylon, middle of shorter span and P1 pier are chosen for inputs and 21 channels are measured for impulse response, that is, Markov parameter has 21 rows and 10 columns in this study. As mentioned above, in 2007, because of system error, only 9 inputs and 16 channels effected, so Markov parameter in 2007 had 16 rows and 9 columns.

Then the Hankel matrix is formed as a block matrix whose size is arbitrary and is defined as 200×100 in this study considering to the results of preliminary calculation. In procedure of singular value decomposition (SVD) to Hankel matrix, small singular values are eliminated with the threshold of 0.015% of the maximum singular value from preliminary calculation.

3. MODAL PARAMETERS AND ANALYSIS

The relationship between natural frequency and temperature is investigated. Vibration data from the sensors placed in pylon and span, totally 16 channels, are collected. Figs. 2 and 3 show the fluctuation of natural frequency along time history in the last three years. Figs. a-c represent the results of 2005, 2006 and 2007 respectively. Although there are up to 6 modes calculated

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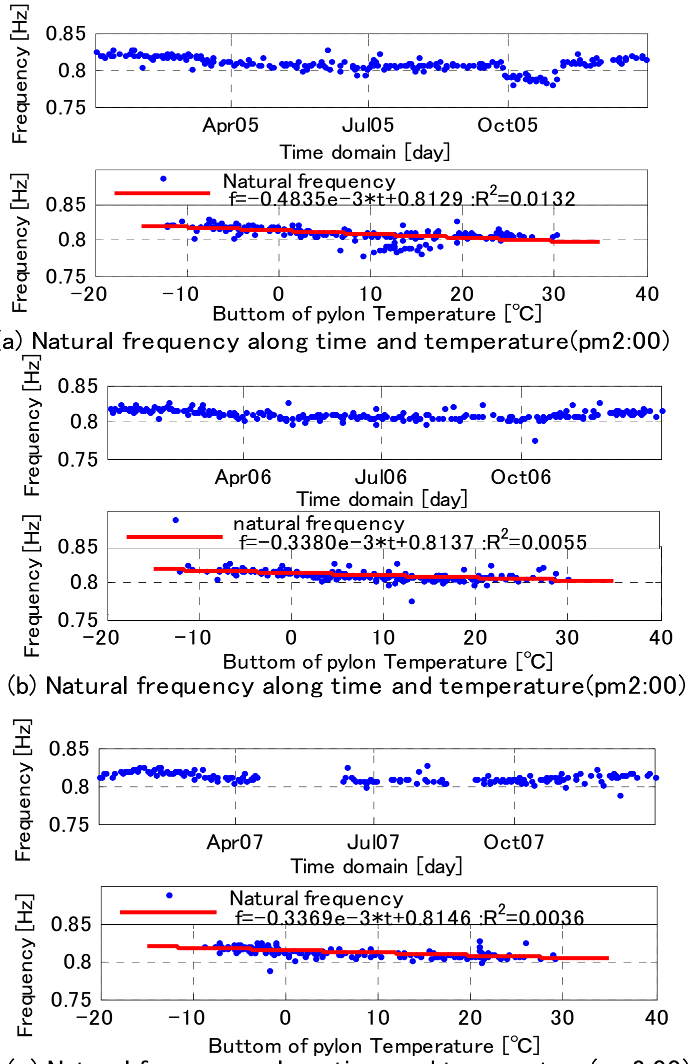
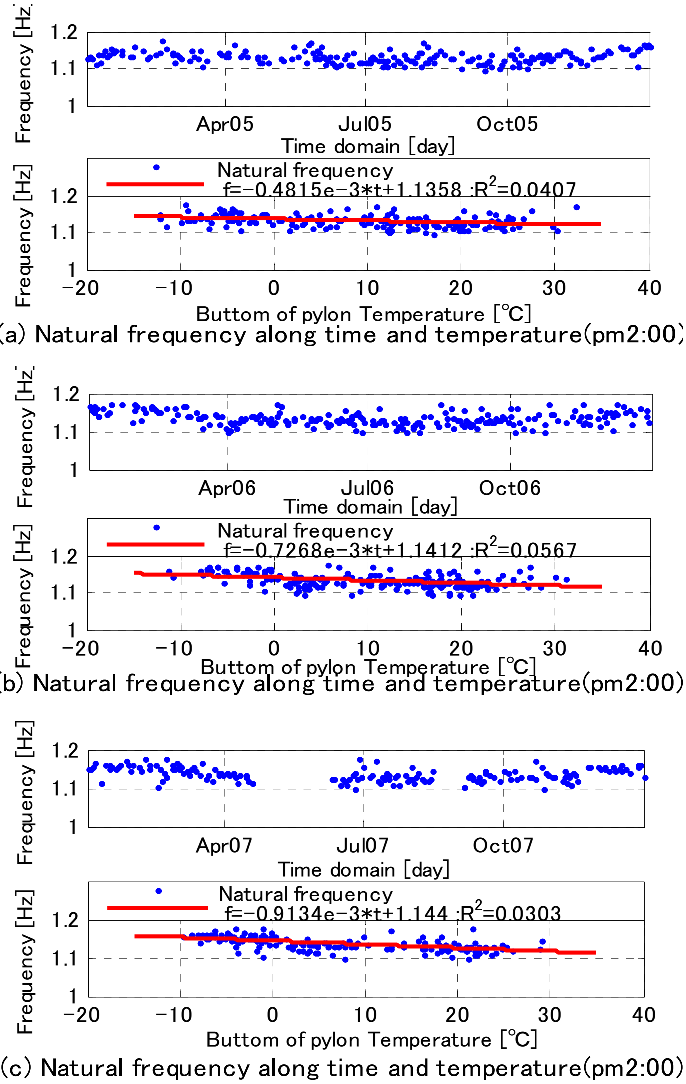


(a) Natural frequency along time and temperature(pm2:00)
(b) Natural frequency along time and temperature(pm2:00)
(c) Natural frequency along time and temperature(pm2:00)

Fig. 2 Fluctuation of the 2nd mode natural frequency



(a) Natural frequency along time and temperature(pm2:00)
(b) Natural frequency along time and temperature(pm2:00)
(c) Natural frequency along time and temperature(pm2:00)

Fig. 3 Fluctuation of the 3rd mode natural frequency

by the ERA, only the 2nd mode and 3rd mode are mentioned as typical examples in this study.

The upper figures from (a), (b), and (c) show natural frequencies fluctuate throughout a cycle year in the very similar manner. In both three years 2005, 2006 and 2007, natural frequency rise up to highest point more than 0.82 Hz in January and goes down to lowest less than 0.80 Hz in August. From three years' observation on this bridge, it has reached the conclusion that natural frequency is affected by seasonal factor throughout the year.

The lower figures from (a), (b), and (c) show natural frequency fluctuates correspond with the temperature of the bottom of pylon. Frequency decreases slowly in a smooth slope while the temperature increases in bottom of pylon. Solid line in each figure shows the least square approximation and sum of the squares of the residual R^2. Though it is small, it is considered a negative correlation between temperature and natural frequency.

Another important phenomenon is the solid line which display the tendency of frequency fluctuation along temperature is changing in each year from 2005 to 2007 both in 2nd and 3rd mode. R^2 increased in 2006 and then decreased in 2007. It means the tendency of frequency change rate fluctuates even in the same temperature condition. The reason and other environmental factors resulted in this phenomenon, probably exist, will be examined.

4. CONCLUSION

In this study, more than 2700 samples of ambient vibration are recorded in 2005, 2006 and 2007 for SHM process of Satsunai Seiryu Bridge. The data are analyzed after applying to NExT and ERA, especially in the relationship between natural frequencies and seasonal fluctuation.

Natural frequency fluctuates seasonally [2]. It is concluded that it increases in cold season, for instance, January, whereas decreases in warm season, for instance, August. Since many factors may contribute to this phenomenon, the reasons are not quantized so far. Natural frequency fluctuates with the change of temperature at bottom of pylon which refers to thermal load in a bounded system, probably partly because the stiffness decreases for increasing temperature and vice versa.

Further research will be focus on eliminating the negative affect of noise in data collecting as much as possible and the quantitative explanation of the reason of relationship between frequency and temperature.

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