Estimation of Damping Ratio for a Cable-Stayed Bridge subjected to an Interference Vortex-Induced Vibration

Sunjoong Kim\textsuperscript{1}, Radiance Calmer\textsuperscript{1} and Ho-Kyung Kim\textsuperscript{1}

\textsuperscript{1}Department of Civil & Environmental Engineering, Seoul National University, Seoul, Korea.

\texttt{fanta909@snu.ac.kr}

Abstract

Structural damping ratio for the first mode of a bridge is estimated to figure out the main source of a vortex-induced vibration (VIV) observed in a parallel twin cable-stayed bridge. Through a series of wind tunnel test, the damping ratio of the bridge seems to be lower than the design value. The damping ratio has been estimated by couple of approaches such as output-only system identification method and TMD-induced forced excitation. Estimated damping ratio varies between 0.20\textendash0.60\% for an average of 0.28\%. This range of damping ratio shows a good agreement with predicted values in wind tunnel tests for the observed vibration in the field. In conclusion, a low structural damping ratio for the first mode has been identified as a source of large VIV for the investigated bridge.

1 Introduction

Considered bridge consists of two cable-stayed bridges connecting Korean peninsula and the Island of Jindo. The first bridge was opened in 1984. As increase of traffic demands rapidly overtook the design capacity of the bridge, the second bridge was planned, and opened in 2005. This second bridge was subjected to extremely large vibrations, especially vortex induced vibration (VIV). When the first vertical mode of the second bridge was excited, the displacement at the center of deck due to wind velocity and vehicle traffic exceeds the acceptable range. This situation overtakes the serviceability condition for wind resistance. The maximum vertical acceleration of the deck is limited at 0.05g under the wind speed of 20 m/s (Korean Society of Civil Engineering, 2006). To better understand VIV for the second bridge, a series of wind tunnel tests (Park et al., 2012) were performed and drew as conclusion that the phenomenon is amplified by the parallel configuration of twin bridges. Moreover, this unexpected amplitude of vibration is accentuated by a low structural damping ratio.

Figure 1: Investigated Cable-stayed bridge
This study intends to estimate the value of structural damping ratio for the first mode using field measurement data and to confirm the assumption drawn by wind tunnel tests (Figure 2). The time domain analysis NExT-ERA (Juan et al., 2004, Dionysius and Yozo, 2008) is employed to estimate damping ratio for the investigated bridge.

![Figure 2: Amplitude of the interference VIV according to the structural damping ratio](image)

**2 Field Measurement**

Measurement data recorded between 10/15/2012 and 10/17/2012 are used for this study. Accelerometers are installed on the top of the tower and at the center of the deck (Figure 3(a)). A vertical acceleration was monitored by two accelerometers (ACC003, ACC005) settled on both sides of the deck (Figure 3(b)). Only vertical acceleration is taken under consideration. Wind velocity is measured by anemometer (WGT004) at the center of the deck of the first bridge. Sampling rate of accelerometer was 100Hz and of anemometer was 10Hz. Duration for each data set was 3600s.

![Figure 3: (a) Layout of the second bridge (b) Sensor position for accelerometers and anemometer](image)
3 Result of NExT-ERA

Figure 4 shows a typical ambient response of vertical acceleration and a power spectral density function, calculated from the impulse response function (IRF) using NExT. To obtain the IRF from NExT, the auto spectral density of the response is first calculated, and then inverse Fourier transform is applied (Caicedo, 2010). Each of parameters are varies a bit according to the PSD of raw data or decaying shape of calculated IRF. The data length for the FFT is set to be $2^{16} - 2^{17}$. In ERA, since the size of Hankel matrix is an important parameter in estimating damping ratio, the size is varied from 1,000 by 1,000 to 5,000 by 5,000 in order to use the 2,000~10,000 data points from the first of the calculated IRF.

Finally, estimated structural damping ratio of the first vertical mode is presented in Figure 5. Averaged value is around 0.301%. This result agrees well with the value expected from wind tunnel tests.
4 Conclusions

This study investigated the source of large vortex induced vibration by implementing the identifying procedures of modal parameters for real bridges using ambient vibration response. Impulse response function was computed by NExT and then, ERA provided modal parameters, particularly damping ratio. In conclusion, the average value of estimated structural damping ratio is 0.282%. This value agrees well with results predicted from previous wind tunnel vibration tests.

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References


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