Analysis on modal frequency variation of a cable-stayed bridge based on monitoring data

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Summary

Although modal parameters are common indexes of structural global conditions, they would be influenced by environmental factors, such as temperature, wind and traffics; therefore it is necessary to investigate the correlations of these environmental factors and the structural modal parameters. Based on the 5 years' monitoring data recorded by Donghai Bridge Structural Health Monitoring System (DBSHMS), this paper studied the first two bending modal frequencies of the main navigation channel bridge (MNCB). The spectral analysis showed that the variation of modal frequencies possessed some dominant cycles such as 1 year, 1 week, 1 day, 12 hours and so on. By correlation analysis and regression analysis, the paper discussed the reasons for those dominant cycles of modal frequency variation from the viewpoint of temperature and traffic loading's effects.

Keywords: Cable Stayed Bridge; Structural Health Monitoring; Modal Frequency Variation; Environmental Factor Effects.

1. Introduction

In last two decades, structural health monitoring (SHM) technology has been widely and systematically used in civil engineering, especially on long-span bridges around the world, for example, Tsing Ma Bridge and Sutong Bridge in Asia, Great Belt Bridge and Tamar Bridge in Europe, and Confederation Bridge and Commodore Barry Bridge in America [1].As increasing of the implementation of SHM in practice, it has turned into a hot topic among academic researchers and engineering practitioners that how to make more efficient use of the measured data. The structural modal parameters, namely, modal frequency, modal shape and modal damping, which are the eigenvalues that can reflect the global condition of structures, are easy to be obtained from ambient vibration measurement, so they are often used as structural condition indicators.

However, extensive studies so far [2-6] have showed that the environmental conditions could cause a relatively large variation of structural dynamic properties, compared to that due to structural damage, therefore it is necessary to explore the relationship between structural dynamic characteristics and environmental factors, such as temperature, traffics, wind properties, humidity and so on. Fortunately, thanks to the advanced SHM system, it becomes possible that massive amounts of data regarding environment and response of structures can be provided on site to improve our understanding on the behaviours of structures.

Based on DBSHMS in Shanghai, the authors have been carrying out bridge condition assessment research since the design stage of DBSHMS. One of the research topics is to identify the effects of environmental factors on structural dynamic properties as well as to clarify their mechanisms. By doing so, it is possible to identify the structural damage more accurately based on the variation of structural modal parameters. Through correlation and coherence analysis by using the monitoring data in 2007, MIN [7-8] found the environmental temperature, traffic-induced vibration intensity and strong wind are the main environmental factors influencing structural modal parameters, and

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furthermore, it was found that these factors play roles in different time scales, i.e., the effect of temperature is in long term scale such as one year, the effect of traffic-induced vibration intensity is in shorter time scale such as one week, while the wind effect is only significant during the strong wind. These results served as a base for this paper.

Using the monitoring data from the DBSHMS during 2007 to 2011, this paper investigates the influence of environmental factors, such as temperature and traffic loads, on the modal parameters of the first two modes of MNCB's girder. For the dominant variation components of modal frequency, e.g. 1 year, 1 week, 1 day and 12 hours, the effects of temperature and traffic contribution are investigated by multiple regression analysis and the mechanisms behind the phenomenon are illustrated.

2. Concluding Remarks

Based on the data of Donghai Bridge Structural Health Monitoring System from 2007 to 2011, this paper investigated the effects of temperature and RMS of response acceleration on the 1st vertical and 1st lateral bending modal frequencies of the bridge at the time scales of 1 year, 1 week, 1 day, and 12 hours. From the above analysis, some conclusions could be drawn:

1) At the year scale, the modal frequency has a negative association with the acceleration RMS or the temperature. For the temperature, the acceleration RMS and the modal frequency, their statistics in 2007 are similar to those over 5 years.

2) The 1st vertical and 1st lateral bending modal frequencies of the bridge are mainly influenced by the temperature and the traffic loading at the time scales of 1 year, 1 week, 1 day and maybe also 12 hours.

3) For different time scales, the relative importance of temperature and the acceleration RMS are different. At one year scale, the temperature is a dominant factor; at one week scale, the traffic loading has greater influence; at one day scale, the traffic loading affects the frequency as much as the temperature; and at 12 hours scale, the traffic loading is dominant while the temperature even can be ignored.

4) The multiple regression model's precision seems to be low, which indicates the data processing of field monitoring data from the actual structures suffers complexity and uncertainty of large degree.

This paper is a preliminary analysis to the monitoring data of Donghai Bridge, performed in a frame of stationary signal and linear system; therefore, the time-dependence of correlation function and PSD is not involved for simplification. It should be studied in the further that the time-frequency analysis on the shorter time scales and the temperature gradient's influence on the modal frequency. This research could serve as a reference for the related researches in structural condition assessment based on monitoring data.

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