The importance of dense monitoring of long-span bridges for its performance re-evaluation

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Summary

Monitoring of structures is expected to offer rich information on structural performance evaluation. While the performance of existing structures may differ from their designs, monitoring of dynamic behaviors potentially provides indications of how close or far the performance is to the designs and unexpected differences that might be important to the safety. In this paper, monitoring of two bridges in Japan as well as dynamic and structural analyses of the monitoring data is presented. Ambient vibration and seismic response records are utilized in performance evaluation of these bridges. The dense sensor instrumentation on the bridges and long-term monitoring provides exceptional opportunities to obtain insight into the behaviors of the bridges and performance of their components.

Keywords: Health monitoring; instrumented bridges; long-span bridges; vibration-based structural assessment.

1. Introduction

Monitoring of structures is expected to facilitate performance evaluation of full-scale structures. The importance of bridge monitoring and performance evaluation is underscored especially after earthquakes such as the 1995 Kobe earthquake. Collapse and damages of bridges exhibit that structures do not necessarily behave as designed or that unanticipated input excitation forces acted. While the performance of existing structures may differ from their designs, monitoring of dynamic behaviors potentially provides indications of how close or far the performance is to the designs. Unexpected differences might be important to the safety.

This paper discusses structural performance evaluation case studies. The research described here involves: (1) modal identification and performance evaluation of the Hakucho Bridge using ambient vibration and (2) modal identification and performance evaluation of the Yokohama-Bay Bridge using series of seismic response records. The emphasis is placed on the benefit of monitoring for global and local structural assessment.

2. Performance evaluation using ambient vibration measurement: case study of Hakucho Suspension Bridge

The Hakucho Bridge in Hokkaido, Japan, was monitored with accelerometers and other sensors to capture its dynamic motion in detail as well as the environmental conditions such as wind velocity. The ambient vibration monitoring with dense instrumentation at sufficiently-high sampling frequency allows detailed analyses of the dynamic properties of the bridge. The modal analysis reveals the characteristics of not only the lower modes, but also the higher modes. The identified modal properties show clear trend; the physical backgrounds of this trend are speculated. The bearing and wind effects are considered causes of the trend and are identified [1].

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3. Performance evaluation using seismic response measurement: case study of Yokohama-Bay Bridge

The Yokohama-Bay Bridge has been monitored by acceleration and displacement sensors on its superstructure and substructure. The long-term monitoring of this bridge allows capturing bridge's dynamic behavior during seismic events. Analyses on six earthquake response records show that the system identification can be used to capture global behavior of the bridge by estimating modal parameters and also to explain local behavior of its component such as performance of link-bearing connections during earthquakes (see Fig.1) [2].

4. Conclusions

Long term monitoring of instrumented bridges offers the opportunity to observe their real performance during ordinary loading conditions or extreme loading events such as earthquakes. This paper has presented vibration monitoring of two bridges and subsequent performance evaluation utilizing ambient vibration measurement and seismic response records. Owing to the dense sensor deployment, excellent quality of measured response, and the recent development of algorithms to deal with the data, the dynamic characteristics of the bridge can be efficiently and accurately estimated. Trends in identified modal properties were observed when these properties were compared with vibration response levels or wind velocity. The physical background of the trends was speculated. Aerodynamic forces and bearing effects of the Hakucho Bridge have been elucidated based on the identified modal properties and their trends. Analysis of Yokohama-Bay Bridge vibration responses clarified the performance of the link bearing connections. While bridge monitoring with large numbers of sensors allowed the performance evaluation in this study, more comprehensive monitoring with denser arrays of sensors and capability to monitor multiple measurands are anticipated to provide deeper insight into structural performance.

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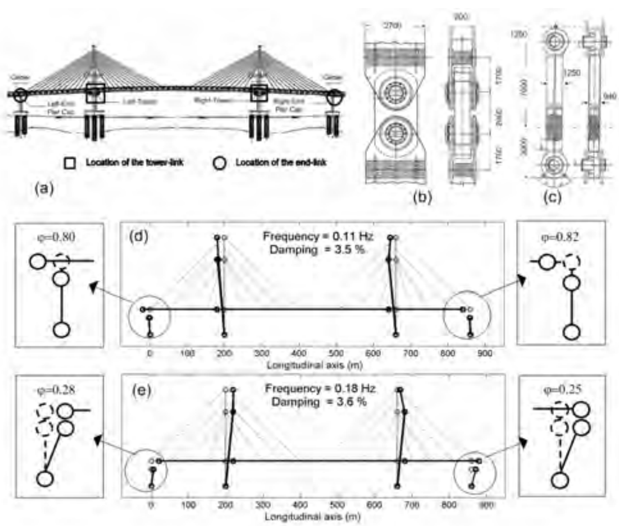

Fig. 1 (a) Location of link bearing connection of Yokohama Bay Bridge. (b) Typical LBC at the tower, (c) typical LBC at end piers. Two of the three typical first modes of Yokohama Bay Bridge identified from the main shock at 17:57 (d) Hinged hinged mode (e) Fixed-fixed mode.