Field Measurement and Load Testing of the Rama IX Cable-Stayed Bridge

Kridayuth CHOMPOOMING
Assistant Professor
Thammasat University
Phathumthani,Thailand
kridayut@tu.ac.th

Kridayuth Chompooming received his PhD degree in civil engineering from Utah State University, USA.

Sayan SIRIMONTREE
Associate Professor
Thammasat University
Phathumthani,Thailand
ssayan@engr.tu.ac.th

Sayan Sirimontree received his PhD degree in civil engineering from Khon Kaen University, Thailand.

Wacharapong PRASARNKLIEO
Lecturer
King Mongkut's Institute of Technology Ladkrabang, Thailand
p.wacharapong@gmail.com

Wacharapong Prasarnklieo received his MEng degree in civil engineering from Thammasat University, Thailand.

Summary

In this paper, field measurement and diagnostic load test carried out for the Rama IX Bridge, as part of bridge in-depth inspection and evaluation is presented. One of the main objectives of the investigation is to better understand the physical behaviors of the aging bridge employing field measurements and to reduce uncertainties, related to material properties, boundary conditions and stiffness contribution as well as any influence of damage and deterioration, in structural evaluation of the bridge structure. A modal analysis is adopted to determine modal properties of the cables, steel box girder, and pylons. A number of three-axle test trucks with predetermined loads are employed in the diagnostic load test. Cable frequencies and strains obtained under the applications of test trucks are presented. A wavelet analysis is adopted for decomposition of strains into static and dynamic components in determination of dynamic effects on structural responses.

Keywords: cable-stayed bridges; field measurement; diagnostic load testing; ambient measurement; spectral analysis; wavelet analysis.

1. Introduction

A number of research and field measurement studies have been reported on an increasing role of modal properties and diagnostic load testing in structural evaluation and health monitoring of aging bridge structures [1]. Due to the fact that the distributions of tension forces among stay cables and bridge dynamic characteristics are directly related to the overall behaviors of the whole bridge structure, the global condition assessment can therefore be evaluated based upon the monitoring records of cable and bridge dynamic responses. Modal characteristics have generally been pointed out to play a significant role in analysis and design as well as health monitoring and preventive maintenance of long-span bridges. As one of the main tasks of the twenty-year, in-depth bridge inspection and evaluation, field measurement of bridge behaviors and diagnostic load testing of the Rama IX Bridge are carried out. The procedure and the results obtained are partly presented in this paper. One of the task objectives is to better understand the overall behaviors and to monitor the global condition of the bridge structure.

2. Description of the RAMA IX Bridge

The Rama IX Bridge, opened to traffic in 1987, is a cable-stayed bridge structure having a main span of 450 m with one central plane configuration of cables anchored in steel pylons on each side of the river. The bridge deck, carrying six traffic lanes, is supported by four sets of 17 locked coil cables with nominal diameters ranging from 121 mm to 167 mm. The total of 68 stay cables, the length of which varies from 48 m to 222 m, is arranged in a semi-harp pattern.

3. Measurement Results

The natural frequencies of the steel box girder are summarized and compared to those previously recorded in Table 1. The corresponding mode shapes are illustratively depicted in Fig. 1. Shifting of natural frequencies of a cable under test truck loading and unloading can be illustrated in Fig. 2.

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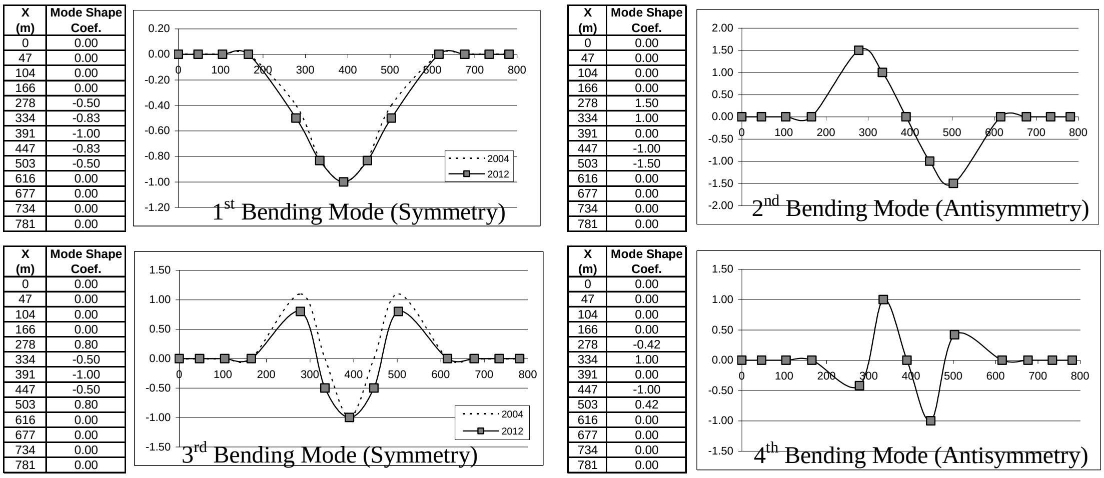
Table 1: Natural Frequencies of Steel Box Girder

Mode	Frequency (Hz) 2004	Frequency (Hz) 2012	% Difference
1st Bending (Symmetry)	0.32	0.32	0.00
2nd Bending (Antisymmetry)	-	0.50	-
3rd Bending (Symmetry)	0.68	0.68	0.00
4th Bending (Antisymmetry)	-	1.01	-
5th Bending (Symmetry)	1.33	1.38	3.76
6st Torsion	1.94	1.93	-0.52
7th Bending (Symmetry)	2.21	2.26	2.26



X (m)	Mode Shape Coef.
0	0.00
47	0.00
104	0.00
166	0.00
278	-0.50
334	-0.83
391	-1.00
447	-0.83
503	-0.50
616	0.00
677	0.00
734	0.00
781	0.00

X (m)	Mode Shape Coef.
0	0.00
47	0.00
104	0.00
166	0.00
278	1.50
334	1.00
391	0.00
447	-1.00
503	-1.50
616	0.00
677	0.00
734	0.00
781	0.00

X (m)	Mode Shape Coef.
0	0.00
47	0.00
104	0.00
166	0.00
278	0.80
334	-0.50
391	-1.00
447	-0.50
503	0.80
616	0.00
677	0.00
734	0.00
781	0.00

X (m)	Mode Shape Coef.
0	0.00
47	0.00
104	0.00
166	0.00
278	-0.42
334	1.00
391	0.00
447	-1.00
503	0.42
616	0.00
677	0.00
734	0.00
781	0.00

Fig 1: Examples of mode shapes of steel box girder

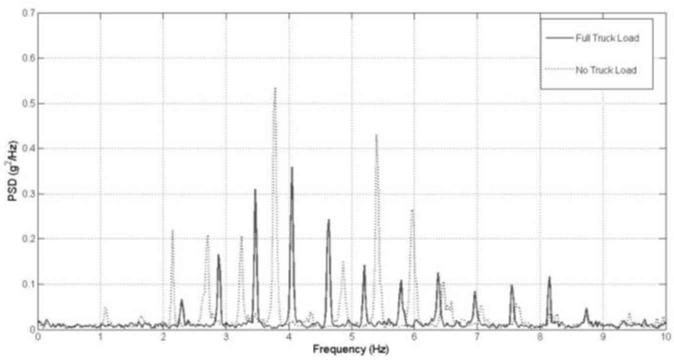


Fig. 2: Shifting of natural frequencies of a cable under test truck loading and unloading

4. Conclusions

The present paper describes a procedure and the results obtained for the field measurement and diagnostic load test of the Rama IX Bridge. The modal properties of the cables, steel box girder, and pylons can be obtained from the field measurement employing modal analysis. Mode shapes of the steel box girder can be determined on the basis of Fourier coefficients. The results obtained in overall are similar to those of the previous measurement carried out in 2004 and significant discrepancies in the bridge modal properties between the two measurements have not been observed. The variations of the cable natural frequencies during test truck loading and unloading are also illustrated. The static and dynamic components of strains can be decomposed through the applications of wavelet analysis for determination of dynamic effects. The results obtained at this stage will be employed for further investigation regarding performance and preventive maintenance of the bridge structure, including finite element modeling validation and updating as well as structural evaluation and development of a health monitoring system.