MODAL ANALYSIS OF CONCRETE BRIDGE DECKS SUBJECTED TO FREE VIBRATION : A RESEARCH PROSPECT

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ABSTRACT

This paper proposes a study on free vibration dynamic analysis for determining vibration parameters such as natural frequencies and mode shapes for two selected bridges in Johor. The vibration parameters for these bridges will be studied using finite element analysis software package ANSYS 6.0. These parameters will be measured by using the vibration dynamic measurement instruments that will be set-up in these bridges. Other data will be obtained from drawing provided by Public Works Department (PWD) that will be used in the analysis using ANSYS 6.0 program. The differences from these two methods will be compared. The modal updating will be used to make the analytical data closer to the field data by using FEM Tools program. The results of such analysis would be useful for early detection of deterioration in bridges and allows suitable maintenance solutions to be applied to the affected structures.

INTRODUCTION

Researchers have proposed a number of monitoring techniques for use in bridge monitoring and damage detection. During the past decade, many research studies have focused on the possibility of using the structural dynamic properties to evaluate structural health. In the simplest form, the dynamic properties typically used are the natural frequencies, mode shapes and modal damping factor.

In Malaysia, there are only a few research works related to bridge health monitoring and the area is still new. Although bridge failures in Malaysia are rare, large stocks of bridges are suffering from deterioration and damage at a small fraction of their design life. Monitoring and assessing structural integrity of existing bridges would be very useful in detecting defects and deterioration at very early stage and helping decision making related to maintenance and rehabilitation. Vibration testing based on dynamic analysis provides one of the effective means of bridge evaluation through the assessment of dynamic properties such as natural frequencies and mode shapes.

LITERATURE REVIEW

Dynamic Testing of Bridges

Dynamic testing techniques rely upon structural response measurements, taken over selected grid points of the bridge from a suitable dynamic excitation source to identify the natural frequencies and mode shapes. Excitation can be provided by either controlled vibration (e.g. use of impact devices, hammers and shakers) and random vibration (e.g. from natural traffic vibration).

Finite element analysis models of the bridge can be established and used to perform analysis for evaluating load carrying capacity or investigation of other performance criteria for the bridge.

Free Vibration

The frequency of the free vibration is an important dimension in vibration analysis and monitoring. In practice, vibrations are 'damped' as a consequence of energy loss and therefore die out (Collacott 1979). Based on research carried out on dynamic tests on large cable-stayed bridge, the free vibration test was performed not only to check the main results of the ambient vibration test but essentially to permit an accurate identification of the damping factors associated with the modes of vibration. It gave more significant contribution to the dynamic response of the bridge particularly under wind loading (Cunha, Caetano and Delgado 2001).

Natural Frequency

A structure's dynamic behaviour is defined by a discrete spectrum of an infinite number of natural frequencies and corresponding mode shapes which are determined by geometry, distribution of mass, stiffness and boundary conditions. Within these parameters, changes in stiffness are directly related to changes in the safety condition of the structure. Therefore, it is essential to identify the damage in the structure by comparing the measured natural frequencies and mode shapes (Chen et al. 1995).

Numerous studies have indicated that an increase in damage reflects decreased natural frequencies of a structure (Chen et al. 1995). Morgan and Oesterle (1985) stated that abnormal loss of stiffness could be inferred when measured natural frequencies are substantially lower than expected. Sun and Hardy (1992) reported continual reduction in natural frequencies as the severity of induced deterioration increased. They reported that the original second and fourth modes, at advanced stages of deterioration, were not present. Various authors have quoted how frequencies have changed with ambient conditions. One extreme case was reported by Aktan (1994) where changes in natural frequency exceeding 5% were due to ambient effects within single day.

Mode Shapes

Once the resonance frequencies of a structure have been found, the mode shapes at each of these frequencies may be determined. Some studies have suggested that changes in mode shapes maybe more sensitive to damage than are natural frequency measurements and also may be able to identify the location. The greatest changes occur in the vicinity of the defect and appear to be more pronounced in the higher modes. In general, the mode shapes of the bridge could be classified as lateral modes, vertical modes, torsional modes and longitudinal modes (Xu et al. 1997). The number of points required to define a mode shape accurately depends the mode and the number of degree of freedom in the system

Instrumentation for Free Vibration Dynamic Measurement of Bridges

The conventional hardware that forms a typical ambient or free vibration bridge testing system comprises of : (1) a set of sensors, commonly accelerometers; (2) amplifier and filter units, covering high gains and providing selectable low-pass filtering with low-cut frequencies to remove all unwanted higher frequencies from the signals; (3) an analog to digital converter capable of digitizing the analog signals and (4) one computer coordinating the data acquisition to perform all on the site data analysis, mode shape animation and printing (Felber 1997).

Computer Analysis: ANSYS Program and FEM Tools Program

ANSYS program (Version 6.0) is a development of Finite Element Model program. It is an effective method of determining the dynamic performance of structures. It will save design time without any mathematical analysis done manually. The designer will spend more time on accurate representation of the intended structure and review of the calculated performance. Furthermore, with interactive graphical facilities, it is possible to generate the complex structure model with considerable ease and to obtain the results in a convenient and readily assimilated form.

FEM Tools program is used to complete the process of dynamic analysis as a modal updating program. This program will help a user in time saving without involving any trial and error method to solve the problems. In other words, this program will give adjusting values of vibration parameters.

THE STUDY

Dynamic testing is performed on bridge structures for the purpose of identification of their in-service structural properties. These properties include the articulation conditions, the effective flexural and torsional rigidities of the deck, the level of damping of principle modes of vibration and also identification of local damages. Identification of these conditions is important to determine support conditions, performing amount of bridge load carrying capacity and condition monitoring of ageing bridge infrastructure.

This study will involve a comparison of experimental work and computer analysis work. Finite element model updating will be developed based on the analysis. The scope of this study is limited to determine the structural dynamic properties such as natural frequencies and mode shapes. Two reinforced concrete bridges in Johor are selected and the dynamic analysis is performed based on free vibration circumstances.

The dynamic measurement instruments will be set up at the proposed location and the ANSYS 6.0 package program is used as a tool of this finite element analysis. The differences between these two methods will be updated by using FEM Tool program.

Objectives

The main objectives for the study of modal analysis of concrete bridge decks subjected to free vibration are stated as follows:

1. to study the technical requirements of instrumentation for free vibration dynamic measurement of bridges;
2. to develop suitable model for modal analysis of two selected bridges.
3. to obtain natural frequencies and mode shapes of selected bridges.
4. to obtain a baseline of the selected bridges using Finite Element Modeling and Updating.

Methodology

A bridge will be selected as a test bridge and the study will involve the following stages :

Preliminary or desk study is the first stage in which several references are used to study the area of interest and obtain some information related to this work. Materials such as books, journals, articles, thesis, seminar notes and conference papers and others are used to obtain information and data for the study. Drawing and inventory documents will provide useful data on the test bridge.

The second stage involves site survey and survey work to be carried out on the selected bridge. Suitable location of dynamic analysis instruments will be proposed. At the same time, analysis by using ANSYS program will be done based on measured properties, dimension and boundary conditions of the bridge.

Finally, the comparison of both data will be made whereby the differences of the data will be subjected to modal updating using FEM Tools in order to get closer value between analytical and experimental analysis.

EXPECTED FINDINGS

Expected findings from this study are :

1. A list of technical specification and logistic requirements of site instrumentation for vibration measurement of a test bridge;
2. A set of in-situ vibrational parameters for baseline vibration signature of a test bridge; and
3. Results of modal updating using Finite Elements Method (FEM) for analysis of vibration response of the bridge due to ambient vibration.

CONCLUSION

Dynamic response has long been recognized as one of the significant factors affecting the service life and safety of bridge structures. Generally, two methods are normally used in obtaining dynamic bridge behavior which are analytical approach and experimental approach. The results from the experimental and analytical approaches can be used as a basis for verifying and updating analytical models of the real life structures. The modal updating from the experiment and numerical approach can be applied as a baseline vibration signature for the studied bridges. The baseline for the bridge will play an important role in the structural health monitoring. Any changes in the bridge behavior due to traffic and environment loading will be detected by monitoring the difference in frequency of baseline.

This study is significance to the sectors that are related to bridge health monitoring such as Public Works Department (PWD), bridge engineers and any related consultancy companies. From this study, they will make an early detection of deterioration in bridges and then suitable maintenance solutions to be applied to the affected structures will be determined.

REFERENCES

Ågårdh, L. and Palm, J. (1992). "Modal Analysis of a Highway Concrete Bridge Excited with Impact." *Proceedings of American Concrete Institute Spring Convention.* Washington

Aktan, A.E. Lee, K.L. Chuntavan, C. and Aksel, T. (1994). "Modal Testing for Structural Identification and Condition Assessment of Constructed Facilities." *Proceedings of 12th International Modal Analysis Conference.* Honolulu, Hawaii.

Calcada, R. Cunha, A. and Delgado, R. (2002). "Dynamic Analysis of Metallic Arch Railway Bridge." *Journal of Bridge Engineering.*

Collacot, R.A. (1979). *Vibration Monitoring and Diagnosis. Techniques for Cost-Effective Plant Maintenance.* The Pitman Press.

Cunha, A. Caetano, E. and Delgado, R. (2001). "Dynamic Tests on Large Cable-Stayed Bridge." *Journal of Bridge Engineering.*

James, M.W.B. Pilate, M. Piotr, O. and Yong, L. (2003). "Assessment of Highway Bridge Upgrading by Dynamic Testing and Finite Element Model Updating." *Journal of Bridge Engineering.*

Morgan, B.J. and Oesterle, R.G. (1985). "On-site Modal Analysis- A New Powerful Inspection Technique." *Proceedings of 2nd International Bridge Conference.* Pittsburg, Pennsylvania.

Slaštan, J. and Pietrzko, S. (1993). "Changes of RC Beam Modal Parameters Due to Cracks." *Proceedings of 11th International Modal Analysis Conference.* Kissimmee, Florida.

Sun, X. and Hardy, H.R. (1992). "An Investigation on Applicability of Modal Analysis as Non-Destructive Evaluation Method in Geotechnical Engineering." *Proceedings 10th International Modal Analysis Conference.* San Diego.

Yang, Y.-B., Liao, S.-S. and Lin, B.-H. (1995). "Impact Formulas for Vehicles Moving Over Simple and Continuous Beams." *Journal of Structural Engineering.*