Vibration testing system for concrete bridges with hammer impact excitation

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1. INTRODUCTION

Visual inspection is required to be conducted prior to condition assessment of existing bridges. The visual inspection cannot avoid subjective nature. Hence, inspection using sensors is expected as a complementary measure to improve the reliability of the condition assessment of existing bridges. In particular, vibration testing has been expected as an effective tool for that. Twayana and Mori [1)] had developed the methodology of vibration test for concrete bridges with hammer impact excitation using only a few portable velocity transducers. However it is time consuming to analyze data by sequential batch processing. Thus the authors cooperatively developed a computer system for effectively interactive processing data obtained through such a vibration test from the point of engineer's view. The objective of this paper is to demonstrate the effectiveness of the developed processing system for vibration test data.

2. PROCEDURE OF STANDARD VIBRATION TEST

A simply or elastically supported span of a bridge can be regarded as a plate from the structural point of view. Such a plate, in case of either a straight or skewed bridge, has natural modes of vibration, which are composed by combination of deformation patterns in two principal axes. The lowest 4 to 6 modes of vibration are focused for overall characteristics of vibration in proposed methodology as illustrated in **Fig. 1**. Higher modes of vibration have nodal lines along which no displacements are. Thus two sensors at points MS and QS are necessary to identify the 4 to 6 modes of vibration with four points of impact at least or nine points for satisfactory condition as illustrated in **Fig. 2**.

Proposed vibration test was conducted on Yoshida Bridge in Ehime Prefecture as demonstration in September 2014. This bridge is a single span, simply supported, prestressed concrete box-beam bridge with 17.2 m length, 10.4 m width and 60 degree skew angle as shown in **Fig. 3**. This bridge constructed in 2011 and it has been studied in detail [1)].

We used three sets of three-component moving-coil type velocity transducers, KVS-300 and three dry-cell battery driven data-loggers, EDR-X7000, manufactured by Kinkei System Corporation , and another three sets of three-component moving-coil type velocity transducers, CR4.5-2S manufactured by ANET for comparison as well. Longitudinal S and A lines were drawn near the curbs at both sides, C line on the center line of the bridge. Three velocity transducers were placed at QS, MS and TQS for

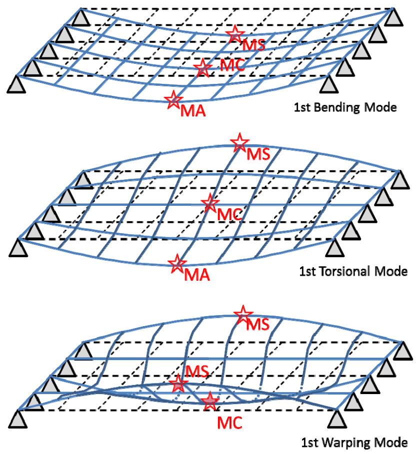


Fig. 1 Lowest three modes of vibration of a plate focused for proposed vibration test

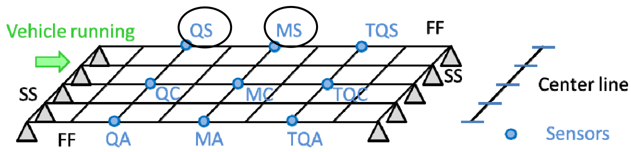


Fig. 2 Two sensors at points MS and QS necessary to identify lowest 4 to 6 modes

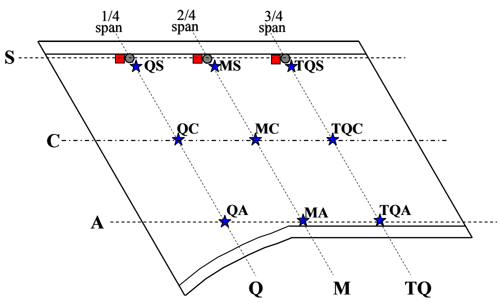


Fig. 3 Arrangement of sensors and impacted points in Yoshida Bridge

permitting traffic lanes to remain open for smooth running of vehicles as shown in **Fig. 4**. Impact excitation was applied at nine points by a wooden hammer. Data sampling frequency was 250 Hz for Kinkei System and 200 Hz for ANET.

3. DATA PROCESSING BY DEVELOPED SYSTEM

We developed an interactive processing system named as Evolutionary Vibration Data Analysis for Generic and Locally Integrated Observation Network, "EVANGELION". The procedure of this interactive data processing system consists of five steps as follows:

1. Reading data from CF cards
2. Extraction of velocity time histories
3. Spectral analysis
4. Filtering with band-pass filters
5. Mode shape identification

4. RESULTS

Fig. 5 shows velocity Fourier spectra at MS point in cases of impact at MC and MA points using data recorded by Kinkei system. Both spectra show clear common peaks at 7.22, 25.01, 32.93 and 57.80 Hz, as numbered as 1, 3, 4 and 5 respectively. On the other hand, a clear peak numbered as 2 at 11.54 Hz appearing in case of impact on MA does not appear in case of impact at MC. This means MC corresponds to the nodal line of the first torsional mode of vibration. The peaks numbered as 1 and 3 correspond to the first bending and the second bending modes respectively.

Fig. 6 shows the snapshots of animation of their mode of vibration using filtered time history data with band-pass filter with regard to corresponding peak frequencies. Thus animation helps us to easily confirm that they are the natural mode of vibration of Yoshida Bridge.

Table 1 shows comparison of time consumption for data processing in each step between sequential batch processing and interactive processing using the developed system. The new system could reduce time consumption to around 10 percent of batch processing in this example.

Fig. 4 Application of proposed vibration test on Yoshida Bridge in Ehime Prefecture

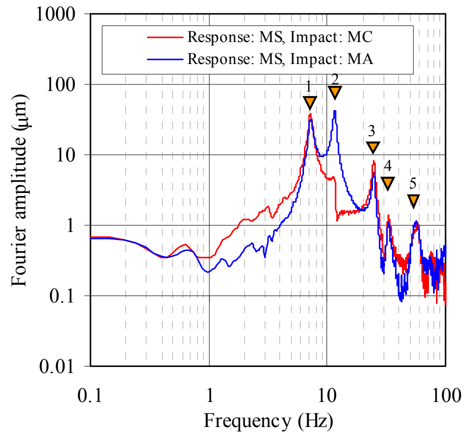
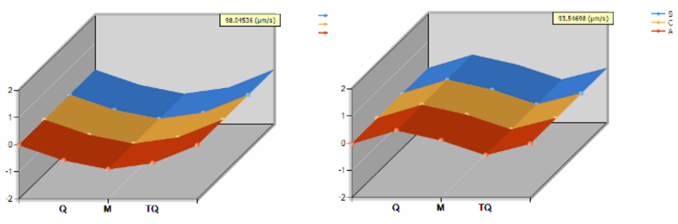


Fig.5 Velocity Fourier spectra at MS obtained in cases of MC and MA impacts



First bending mode (7.22 Hz)

Second bending mode (25.01 Hz)

Fig.6 First bending and second bending modes of Yoshida Bridge

Table 1 Comparison of time consumption for data processing between sequential batch processing and developed system

	Time consume (minute)	
Analysis steps	Microsoft Excel	Evangelion
1. Read the data from CF cards	15	15
2. Extraction of Velocity time histories	105	20
3. Spectral analysis	635	80
4. Filtering	1560	155
5. Mode shape identification	540	30
Total time consume	2855	300

5. CONCLUSIONS

Our newly developed processing system for vibration test data reduces time consumption to 10 percent comparing to sequential batch processing, and improve the reliability of natural mode identification. As a result, preliminary analysis of vibration test can be carried out at a test site in a day.

REFERENCE: 1) Ratna Prasad Twayana, Shinichiro Mori: Changes of natural frequencies of a short-span concrete skew bridge during construction, Journal of Structural Engineering, JSCE, Vol. 60A, pp. 501-512, 2014.