Experimental Studies on Vibration Properties Changes of Bridge with RC Piers under Different Vibration Levels

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1. Introduction

In order to determine the changes of vibration properties such as the natural frequency and damping ratio under a series of different vibration levels, several vibration tests with a wide range of amplitudes were carried out under excitation with relatively small amplitude levels[2]. In particular, an experimental study of ambient and free vibrations testing of a simple RC bridge model and actual bridge"Shin-Tashiro Bridge" were carried out. Generally, based on the results of these vibration tests with various amplitude levels, the amplitude dependence on vibration properties was remarkable.

2. Outline of vibration tests

(1) Experimental bridge model

Free vibration tests have been undertaken for a single span RC viaduct bridge model consists of superstructure, two piers, and two laminated rubber bearings. The details of the specimens are shown in **Fig. 1**. As illustrated in this figure, the fixed support conditions were idealized by combining the pier footing and two steel I-girders to the shaking table by bolts. In addition, the superstructure was connected to the piers through laminated rubber bearings. To understand the dependency of vibration properties on response amplitude, several free vibration experiments were carried out with a wide range of amplitudes for the two pier models that make up the bridge model and for the entire bridge model. The free vibration excitation was applied by hummer impact at the top of the models. The acceleration responses were derived from the experimental results provided by free vibration tests in the longitudinal axis at top of the structure. As an example, an acceleration response waveform of the free vibration and its Fourier spectrum that was obtained from the pier model are shown in the top and middle figures of **Fig. 2**. From Fourier spectrum graph, it can be observed that two dominant frequencies have confirmed the primary and secondary modes. Thereafter filtering the free vibration waveform, the damping ratio was identified from the relationship of the acceleration amplitude and number of cycles for the peak of each cycle in the waveform as shown in lowest figure of **Fig. 2**.

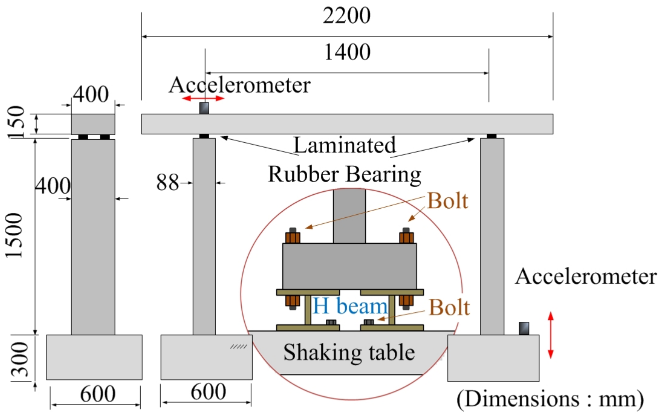

Fig. 1 Bridge model

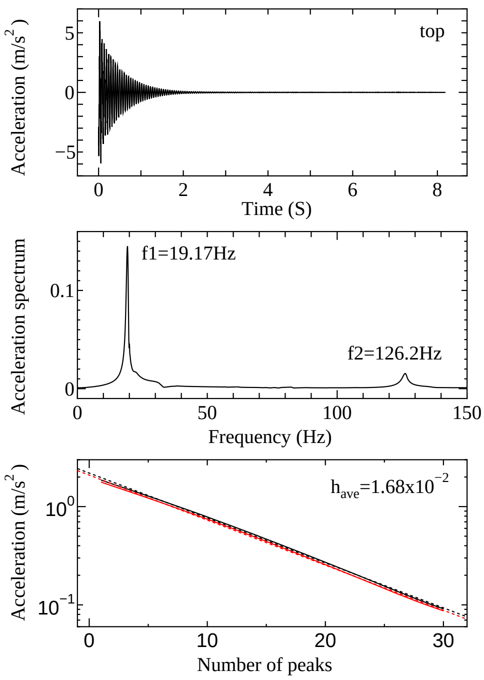

Fig. 2 Free vibration properties of pier model

(2) Actual bridge (Shin-Tashiro Bridge)

A series of ambient and free vibration experiments were conducted on Shin-Tashiro Bridge which is located in Nasu-Shiobara, Tochigi Prefecture, Japan. As shown in **Photo 1**, Shin-Tashiro Bridge is two-span continuous steel girders, with an oval shape single RC pier in the middle and two abutments. Laminated rubber bearings connect between the superstructure and piers. In 2010, before setting up the superstructure of the bridge, ambient and free vibration tests were carried out of the single pier of the bridge. Then after constructing the superstructure, ambient and free vibration tests of the entire bridge took place again in 2011. In the two cases, the free vibration consisted by people jumping at the top of the structures with different vibration levels.

In each measurement, the velocity responses in the longitudinal, transverse, and vertical direction were recorded. The upper and the middle figures of **Fig.**

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Photo 1 Shin-Tashiro Bridge

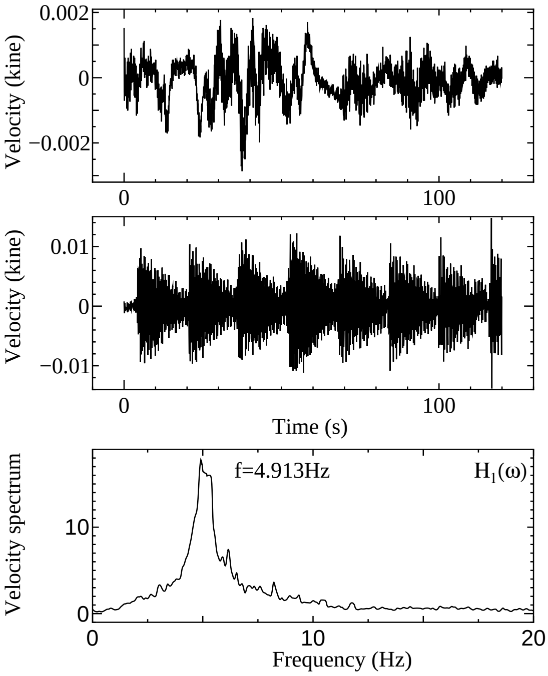

Fig. 3 Microtremor and free vibration properties

3 illustrate, respectively, an example of the ambient and free vibration waveforms of Shin-Tashiro Bridge. Cross-spectral analysis was performed to the recorded waveforms to reduce the noise effect of the ambient measurements[1]. In the lowest figure of **Fig. 3**, the natural frequency was taken as the dominant frequency of the transfer function between the ground acceleration and the top of the pier acceleration. Moreover, ambient vibration waveforms were formed by filtering the time history waveforms using the autocorrelation function, then the damping ratio estimated by the RD method. On the other hand, the natural frequency of free vibration waveforms was generated by using the FFT analysis method. Furthermore, the damping ratio has been identified from the relation between the peak of each cycle and the number of cycles of the free vibration waveform.

3. Vibration characteristics of bridge model and Shin-Tashiro Bridge

First, the results of a series of free vibration tests of the bridge model and the two single pier models that make up the entire bridge model are carried out. In case of the pier model, the primary and secondary modes were observed, while in case of the bridge model only the primary mode was observed. As a result, **Fig. 4** shows the relationship of the maximum acceleration amplitude versus the damping ratios of each identified vibration level of the primary and secondary modes of the

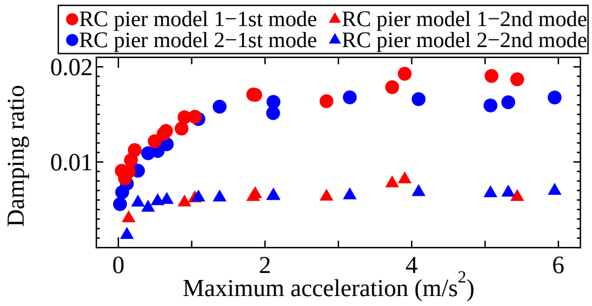

Fig. 4 Damping ratio-acceleration amplitude relationship of two pier models

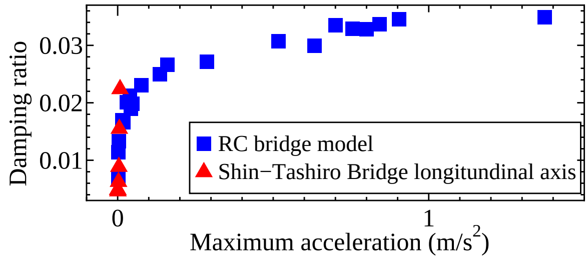

Fig. 5 Damping ratio-acceleration amplitude relationship of bridge model and Shin-Tashiro Bridge

two piers. This figure shows that the damping ratio of the secondary mode is smaller than the one of the first mode, and this is justified to the influence of the amplitude dependence which is smaller in secondary mode. Additionally, the figure illustrates that a similar dependency of the amplitude levels on damping ratio of the primary and secondary modes. Herein, as the maximum acceleration amplitude increases, the damping ratio increases remarkably. Whereas, although it is not shown in figures, it was pointed out that as the maximum acceleration amplitude increases, the natural frequency tends to decrease. These results are similar to that obtained from vibration records from the entire bridge model and in the longitudinal and transverse axis of Shin-tashiro Bridge. Furthermore, **Fig. 5** illustrates the relationship between the damping ratio and the maximum acceleration of different vibration level amplitude of the bridge model and Shin-Tashiro Bridge. The two graphs confirm that the damping ratio of the bridge model and the actual bridge are similar in the small amplitude levels.

4. Conclusion

In this study, different levels of vibration experiments with different amplitude level were conducted of bridge model and Shin-Tashiro Bridge. The results of the series of vibration tests over a wide range of amplitude levels can be summarized as follows.

- As the response amplitude becomes large, natural frequency decreases and damping ratio increases.
- The damping ratios of the second mode were smaller than the one of the first mode in this experiment.
- The damping ratios of bridge model and actual bridge were similar in small amplitude range.

REFERENCES

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2) Saito, T. et. al. : Experimental investigation on vibrational property change of bridge model under various input level, Journal of Structural Engineering, Vol.59A, 2013 (in Japanese).