Modal Identification of Elevated Bridge through Microtremor and Impact Tests using Frequency Domain Decomposition

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1. INTRODUCTION

Modal identification is now widely used recent years in civil engineering structures to understand the dynamic behavior of structures. Frequency domain decomposition (FDD) is a well-known technique which is applied to output-only system and input is assumed as white noise referred in Brinker et al. (2001). Therefore, microtremor which is a low amplitude ambient vibration is widely used in FDD to obtain modal parameters. Impact test is also used to identify modal parameters through input and output systems. However, impact can be considered as a transient impulse which means that the input response can be assumed as white noise. Therefore, in this study, FDD is applied to impact test and microtremor via a continuous span bridge in order to demonstrate the feasibility of applying FDD to impact test, and to compare the differences between applying FDD to microtremor and impact test.

During the construction of an elevated bridge, when two single span bridges are connected, modal parameters might change substantially. It is important to understand the changes of modal parameters on different construction stages especially while doing earthquake-resistant design. Therefore, the continuous span bridge is compared with a single span bridge which is the preliminary constructed part of the continuous one. The result of the single span bridge is referred in Morikawa et al. (2019).

2. FIELD OBSERVATION

Fig. 1 shows the profile after the construction of the elevated bridge, and only R2, Ct3, R3, and Ct4 parts enclosed with the red frame were connected during the observation. R2 part is the preliminary constructed part mentioned previously, and Ct3 and Ct4 parts are supported with rubber support on the superstructure. As shown in Fig.2, two types of data logger (AK and OTK) with velocity sensors (KVS300) of natural frequency 2 Hz and one type of data logger (LS8800) with accelerometers (Titan) were set on the superstructure (R2,Ct3, and R3), and these three parts are used for calculation.

The calculation condition for the fast Fourier transform is as follows: n_{ak}=4096, dt_{ak}=0.01 sec for AK, and n_{OTK}=n_{Titan}=8192, dt_{OTK}=dt_{Titan}=0.005 sec for OTK and Titan, where n_* stands for numbers of points to calculate Fourier transform, dt_* stands for time interval, and $*$ stands for sensors and data loggers. The numbers of ensemble average for calculating power spectra are 8 for microtremor data and 4 to 6 for data of impact test. In the calculation, the T#5 (T stands for Titan sensor) is anomalous in the impact tests, thus, T#5 sensor is used only in the microtremor.

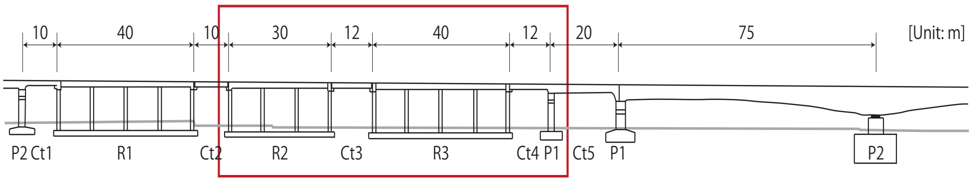

Fig. 1 Profile of the observed bridge

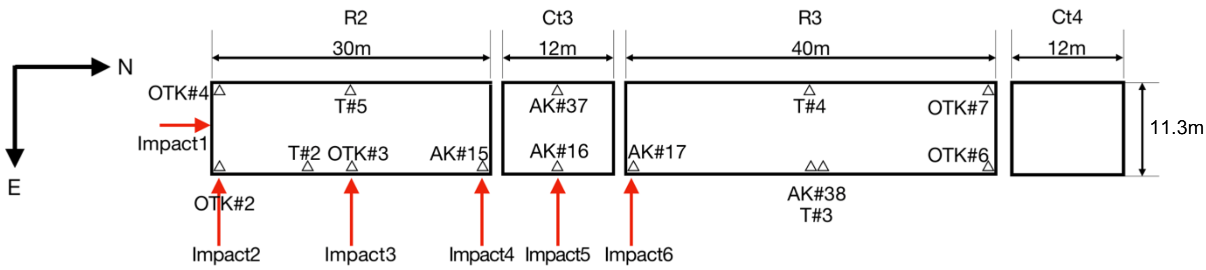

Fig. 2 Locations of the sensors and impact tests

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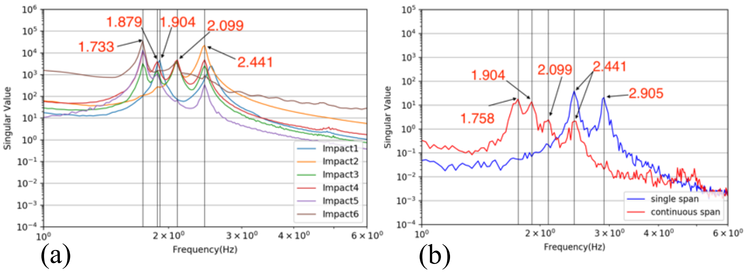
3. RESULTS AND DISCUSSION

Fig. 3(a) shows the first singular values of each impact test and Fig. 3(b) shows the first singular values of microtremor for both single and continuous span bridges. It is observed from Fig. 3 that one peak at 1.879 Hz, which doesn't exist for microtremor data, is excited by the impact test, and it is closed to another peak at 1.904 Hz. This means that these two peaks suggest closed modes. As Table 1 shows the peak frequencies and mode shapes of the continuous span bridge, the two mode shapes show completely different at the closed two peaks. For continuous structures, some closed modes might disappear and the modes are hard to be separated into SDOF system clearly. The impact test can excite closed mode that doesn't appear in microtremor depending on the location of impact.

The singular values of microtremor shown in Fig. 3(b) shows four peaks (1.758 Hz, 1.904 Hz, 2.099 Hz and 2.441 Hz) and two peaks (2.441Hz and 05Hz) for continuous span and single span, respectively. The peak frequency of the continuous span at 2.441Hz is identical to that of single span. Table 2 shows the peak frequencies and mode shapes for the single span bridge. From Table 1 and Table 2, the mode shapes are different at 2.441 Hz and peak at 2.905 Hz for single span bridge disappear for the continuous span bridge. Furthermore, it is observed from Table 1 and Fig. 3(b) that peaks appear at lower frequencies during the construction from the single to the continuous span. This suggests that modal properties of the continuous structure should be considered for an earthquake-resistant design.

It is noted that the mode shapes for the real part of mode vector are almost identical to those for the absolute value as shown in Table1 and 2. This means that the damping of the system can be dealt with a proportional viscous damping, which is proportional to a linear combination of mass and stiffness.



(a) (b)

Fig. 3 (a) 1st singular values of impact1~impact6 (b) singular values of microtremor for both single and continuous span bridge

Table 2 Peak frequencies and mode shapes of the single span bridge

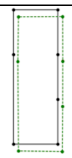
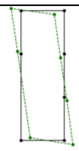
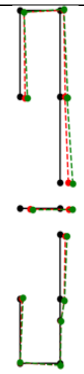
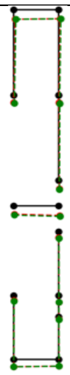
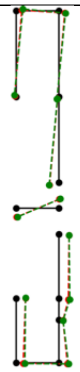
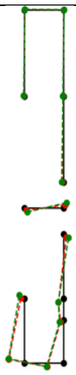
Mode Shape ----real part of modal vector ----absolute part of modal vector Unit : Hz		
Case/Peaks	Peak1	Peak2
Microtremor&Impact1,3	2.441	2.905
Impact2	2.441	2.930

Table 1 Peak frequencies and mode shapes of the continuous span bridge

Mode Shape ----real part of modal vector ----absolute part of modal vector Unit : Hz					
Cases/ Peaks	Peak1	Peak2	Peak3	Peak4	Peak5
Microtremor	1.758	—	1.904	2.099	2.441
Impact1	—	—	1.904	—	—
Impact2	—	—	—	2.099	2.441
Impact3	1.733	1.879	—	2.099	2.441
Impact4	1.733	1.879	—	2.099	2.441
Impact5	1.733	1.879	—	—	2.441
Impact6	1.733	—	—	2.099	2.441

4. CONCLUSIONS AND FUTURE STUDY

In this study, three conclusions are obtained, (1) Impact test can excite closed mode that doesn't appear in microtremor. (2) Modal properties of the continuous structure should be considered for an earthquake-resistant design. (3) A proportional viscous damping can be applied for an earthquake-resistant design.

In the future study, numerical simulations will be performed in order to identify a structural model on a basis of the results from field observations.

REFERENCES

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