Field vibration tests on natural vibration characteristics of 5-span continuous PC rigid-frame box girder bridge

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1. Introduction

Structural Health Monitoring (SHM) of the bridge is very important to prolong those operating life span. Many researchers have been tried to investigate the dynamic properties of new and/or existing bridges by conducting some kinds of vibration tests and/or performing finite element analysis[1)-3)]. To better control and operation for the bridge management based on the SHM, it is very important that the natural vibration characteristics of the bridge were investigated just after completion.

From this point of view, in order to investigate the natural vibration characteristics of a five-span continuous PC box-girder bridge which has not opened the traffic yet and to get the initial values for the better control for the bridge, the field vibration tests were conducted. Here, the outline of vibration test results is reported.

2. Overview of experiment

2.1 Test site

The Obirashike-river Bridge is five-span continuous PC rigid-frame box girder bridge with a center span of 136 m, located in the east part of Hokkaido, Japan, which was completed in 2015. Fig. 1 shows a bird's eye view of the Obirashike-river Bridge. The characteristics of the bridge are summarized in Table 1 .

2.2 Measuring system

A total of 34 high-sensitive servo-type vibration meters were placed on both sides of the slab to accurately evaluate the natural vibration frequencies and modes of the bridge as shown in Fig. 2 . The acceleration response of the bridge was monitored after passing a weight control vehicle (a dump truck with a total mass of 185 kN, see Fig. 3) by means of a wireless LAN system. And also, excitation of the human jumping was recorded. The measured data were recorded in notebook computers, in which

Table 1　Characteristics of Obirashike-river Bridge

Design	Five-span continuous PC rigid-frame box girder
Total length	392 m (40+88+136+88+40 m)
Width	10.51 m
Girder height	3.5 ～ 7.5 m
Completion	2015
Longitudinal gradient	0.31 %

Figure 1　View of Obirashike-river bridge[4)]

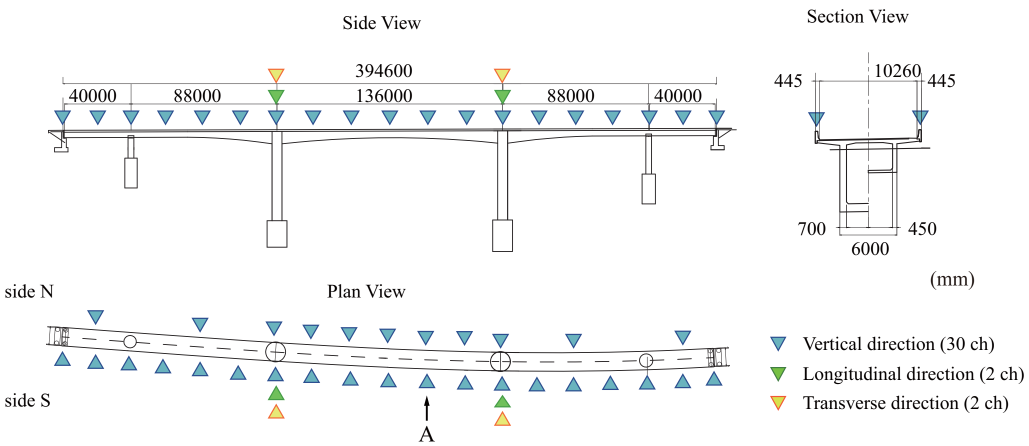


Figure 2　Location of measuring points

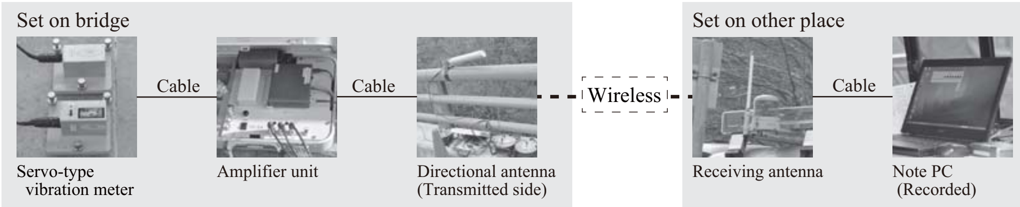


Figure 4　Wireless LAN system

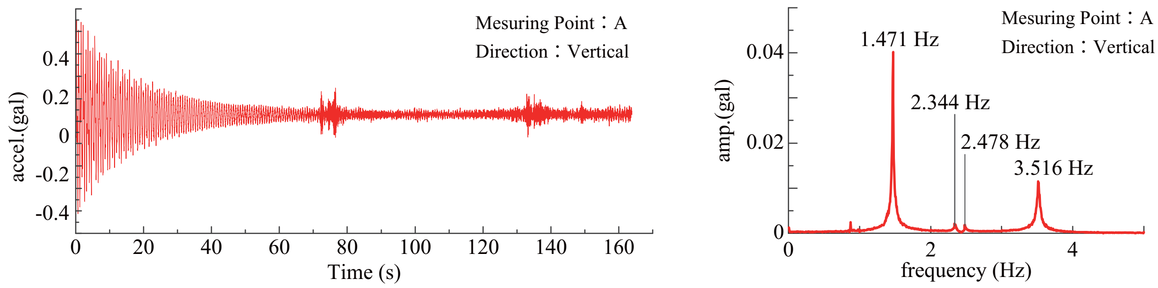


Figure 5　Acceleration response and Fourier spectrum of point A

Figure 3　Weight contral truck was used in test

sampling time of the data was set to 5 ms (200 Hz) while the bridge was closed to other traffic. Fig. 4 shows a wireless LAN system applied in these field tests.

2.3 Evaluation of dynamic characteristics of bridge

Many experimental techniques have been established for evaluating dynamic characteristics (natural vibration frequencies and modes) of the existing bridges. In this study, vibration characteristics of the bridge were investigated by using Fourier spectrum of acceleration response at each measuring point. The vibration modes were obtained based on the following procedures[4), 5)]:

1. Fourier spectrum of acceleration time history (time: 163.84 s) at each measuring point after vehicles passing was obtained;
2. The predominant natural vibration frequencies were specified inspecting Fourier spectrum at the marked point;
3. Time histories of the harmonic vibration with the predominant frequency at the whole measuring points were numerically made using Fourier and phase spectra;
4. Acceleration amplitudes at each one-fourth period of the harmonic vibration were plotted at the whole measuring points; and
5. Uncoupled natural vibration mode was specified confirming no significant difference among the modes at every one-fourth period.

3. Experimental results and discussions

3.1 Time history of acceleration and its Fourier spectrum

Fig. 5 shows an example of acceleration response and its Fourier spectrum at point A in the cases with truck velocity 60 km/h. The maximum and minimum amplitude of the acceleration response for free vibrations were distributed in the range of about ± 0.6 gal.

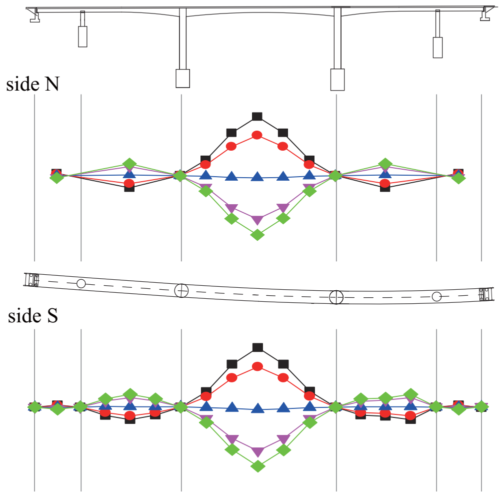
The maximum values of the Fourier spectrum are clearly indicated at some frequencies, and the frequencies corresponding to these maximum spectral values are chosen as predominant ones in this study. The obtained maximum amplitudes corresponding to the peak of the diagram (see, Fig. 5) were 1.471, 2.344, 2.478, and 3.516 Hz.

3.2 Vibration modes

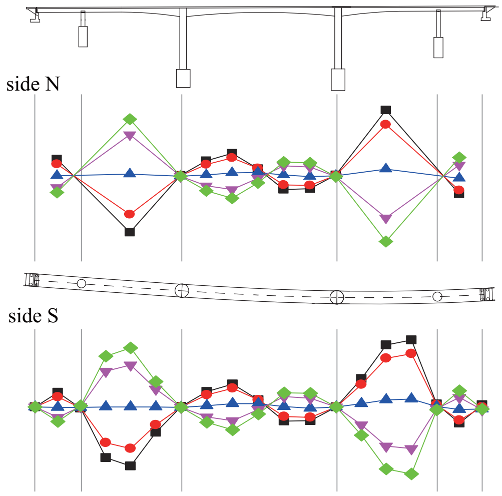
Fig. 6 shows mode shapes for all natural vibration frequencies which are specified applying above evaluation method for acceleration response obtained after passing traffic. All modes are normalized with respect to the maximum amplitude at the side N of the bridge.

From these figures, it is confirmed that in case of the 3rd flexural vibration mode (see, Figure 6c), mode shapes in both side spans are not equal to each other. However, since other mode shapes are almost symmetry, the natural vibration frequencies and mode shapes can be evaluated by field vibration test.

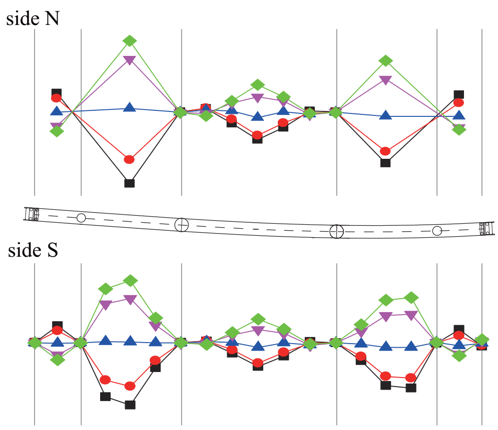
Table 2 lists the comparison of the natural vibration frequencies among three results obtained from two kinds of acceleration responses after the passing truck, and the excitation of the human jumping. From this table, it was confirmed that the fundamental natural frequency can also be specified even in human excitation which is the simplest vibration method.



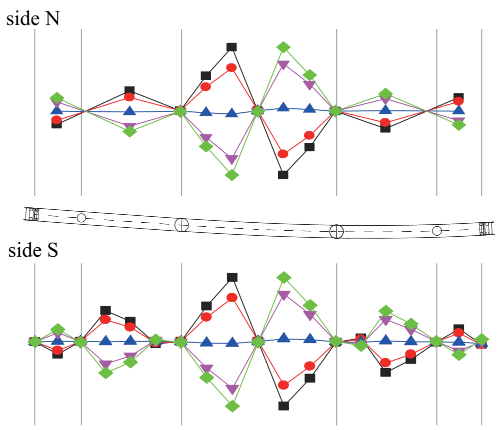
(a) 1st vibration mode ($f_1 = 1.471$ Hz)



(b) 2nd vibration mode ($f_2 = 2.344$ Hz)



(c) 3rd vibration mode ($f_3 = 2.478$ Hz)



(d) 4th vibration mode ($f_4 = 3.516$ Hz)

Figure 6　Natural vibration modes obtained from field test

Table 2　Comparison of natural vibration frequencies

Vibration mode	Frequency (Hz)		
	Velocity V (km/h)		Human Jumping
	40	60	
1st	1.471	1.471	1.471
2nd	-	2.344	-
3rd	2.478	2.478	-
4th	3.516	3.516	-

4.　Conclusion

In order to investigate the initial vibration characteristics for the better control and operation for the 5-span continuous PC girder bridge which has not opened the traffic yet, the field vibration tests were conducted. The bridge response was monitored under ambient vibration after the passing of traffic and the excitation of the human jumping. The results obtained from this study were as follows:

1) The natural vibration frequencies and modes of the bridge can be appropriately evaluated by conducting an ambient vibration test;

2) The fundamental natural vibration and modes can be specified by the excitation of the human jumping which are easy and convenient methods even though the 5-span continuous PC bridge.

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