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Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 223-224
20-22 November, 2013

Non-contact Inspection Method for Structure using High Power Sound Source —Examination of Detectable Size and Depth—

強力音源を用いた構造物の非接触検査法—検出可能な平面規模・深さの検討 —

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1. Introduction

We study about a non-contact inspection method (1) for large-scale structures such as a tunnel and a bridge. This method consists of a high powered sound source and a scanning laser Doppler vibrometer (SLDV). In our previous study, we propose a tone burst wave method (2) to improve signal-to-noise ratio (SNR). Using this method, the defect that was difficult to be detected by using our previous method became to be detected. In this paper, we examined the detectable size and depth by using the tone burst wave method.

2. Defect detection principle

If a defect parallel to a concrete surface exists in a shallow part under concrete surface as shown in Fig. 1, the upper part on the defect behaves like a vibrating plate. Therefore, the defective part has a flexural resonance frequency. The flexural resonance frequency is resonated by airborne sound wave, which contains the resonance frequency. The vibration signal on the concrete surface is optically detected by the SLDV.

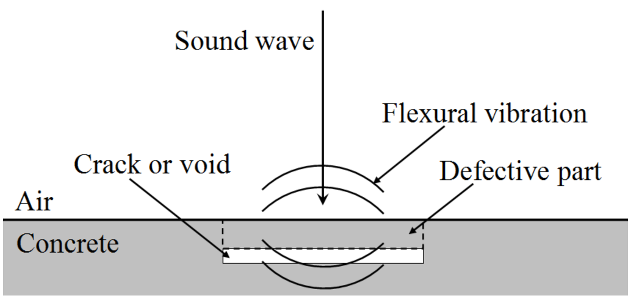


Fig. 1 Defect detection principle.

Assuming that an existing defect is circular shape, defective part can be approximated as a simply supported circular plate. Thus, its first natural frequency f is indicated (3) by

$$f = \frac{4.98}{2\pi a^2}\sqrt{\frac{Eh^2}{12\rho(1-\upsilon^2)}} \qquad (1)$$

Here, a is radius, h is thickness of plate, E is Young's modulus, ρ is density and ν is Poisson's ratio. From this formula, it is confirmed that the natural frequency is proportional to the thickness, inversely proportional to the radius.

3. Experiment using concrete wall test piece

An experiment using a concrete wall test piece, which has artificial defects, is carried out to examine the detectable size and depth.

3.1 Experimental setup

Fabricated concrete wall test piece (2.0×1.5×0.3 m^3) has circular styrofoam boards as a cavity defect as shown in Fig. 2. Figure 3 shows an experimental setup. An LRAD (LRAD Corp., LRAD 300X) is employed as a sound source in this study. Tone burst waves, which contains a frequency band from 500 to 7000 Hz, is utilized for the frequency response measurement. SPL of approx. 100 dB re 20 micro Pa is emitted near the concrete surface. The excited vibration velocity on the concrete surface is measured by the SLDV (Polytec Corp., PSV-400-H4). Measured point is center position of the defective part. Signal averaging number is 5.

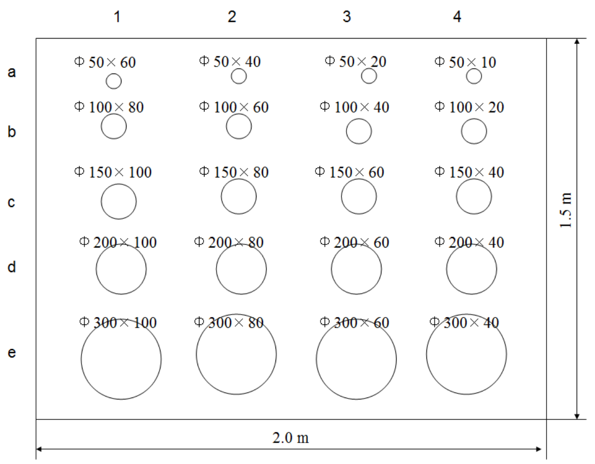


Fig. 2 Fabricated concrete wall test piece. Diameters of the specimens are from 10 to 300 mm, and thicknesses are from 10 to 100 mm.

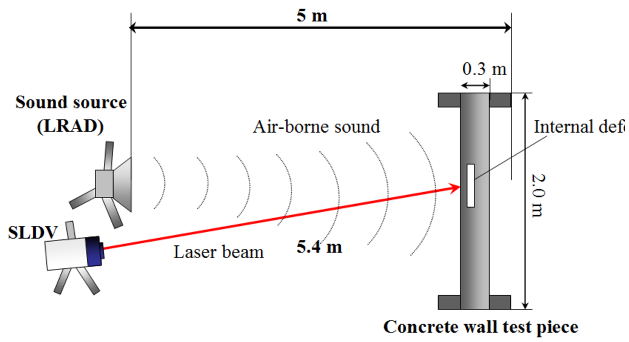


Fig. 3 Experimental setup using concrete wall test piece.

3.1 Experimental result

The frequencies as indicated in Table 1 are detected peak frequencies. The smaller and deeper defect is, the weaker the detected signal is. In these specimens, the peak of flexural resonance frequency can be observed as shown in Table 1.

Table 1 Detected natural frequency peak of each specimen.

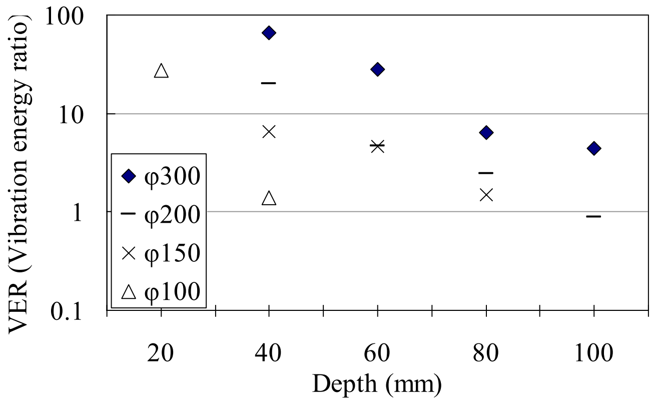
	d : 100	d : 80	d : 60	d : 40	d : 20
φ100	-	×	×	×	5430 Hz
φ150	×	×	4958 Hz	4449 Hz	-
φ200	4557 Hz	4389 Hz	3733 Hz	2762 Hz	-
φ300	3155 Hz	2734 Hz	2106 Hz	1449 Hz	-

3.2 Defect evaluation using energy ratio

The measured result is evaluated by vibration energy ratio [(4)]. The vibration energy ratio is ratio between the vibration energy of defective part and healthy part, which has a flat frequency characteristic. The vibration energy ratio : VER is indicated by

$$VER = \frac{\int_{\omega_1}^{\omega_2} (PSD_{defect}) d\omega}{\int_{\omega_1}^{\omega_2} (PSD_{health}) d\omega} \qquad (2)$$

Here, PSD_{defect} and PSD_{health} are power spectrum densities of a defective part and a healthy part, ω_1 and ω_2 are start and end angular frequency, respectively. Figure 4 shows the calculated vibration energy ratio. From this figure, the correlation between the energy ratio and the depth



of defect can be seen.

Fig. 4 Vibration energy ratio between the defective and healthy part.

4. Conclusions

We examined the detectable size and depth by tone burst wave method. As a result, the defect signal in a depth of 100 mm can be observed regarding φ200 mm. In addition, it is suggested that a certain level of estimation of a depth can be available by vibration energy ratio evaluation method.

Acknowledgment

This work was supported by Ministry of Land, Infrastructure, Transport and Tourism, technology research development to contribute to improvement of the quality of the road policy (2012).

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