A FUNDAMENTAL STUDY ON THE DIAGNOSTIC MEASURE OF CONCRETE STRUCTURE USING HAMMERING SOUND TEST

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1. INTRODUCTION

Recently, the deterioration of concrete structures becomes a major problem to most of the social infrastructures facilities, which constructed during the high economic growth period in Japan. Therefore, to maintain the existing structures and to prevent those from unexpected accident become significant issues to civil engineers. Nondestructive testing is a useful method of observing, testing and evaluating on inspection without damaging the serviceability of structures. A hammering sound test, one of the most convenient methods to diagnosis deterioration in concrete structures, has been widely applied to inspecting fields since it can immediately identify the difference between defective spots and healthy spots by listening to a vague difference of sound produced by a hammer. However, this method generally depends on the subjective sense of each inspector to distinguish defective spots. In this study, two types of hammering test are tested on concrete bridges, and the characteristics of hammering sound pressure are compared between them. Besides, the accuracy of detecting defective parts between both testing hammers is examined.

2. HAMMERING TEST

In this study, impulse hammering test and rotary hammering test are conducted on two in-service bridges with four different girders. To investigate the accuracy of rotary hammering test, an impulse hammer is used in the test for comparison. In an impulse hammering test, a sound pressure sensor is placed about 5cm away from the hammering point as shown in Photo 1. For Photo 2, it is a rotary hammering sound tester which has a polyhedron metal attached on the rod tip. During the measurement, the polyhedron metal part is rolled on the concrete surface to generate an impact sound, after that analyzing sound data to gain frequency spectrum. The time history data of sound pressure are simultaneously recorded by the Fast Fourier Transform analyzer and the hammering sound data are recorded 5 times by 51.2 kHz sampling frequency at each point.

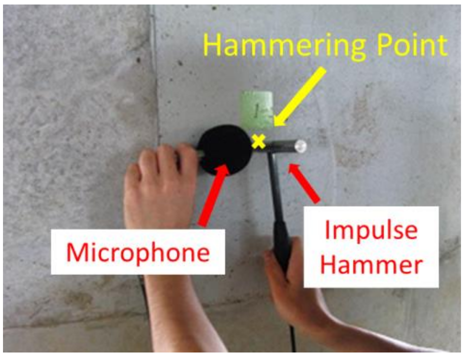

Photo 1 Impulse hammering test

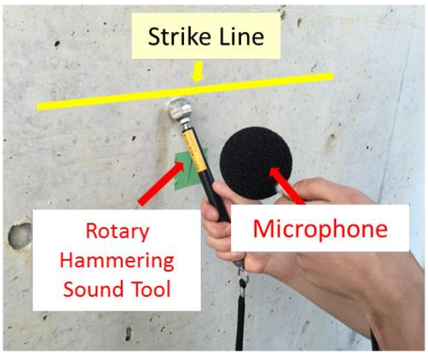

Photo 2 Rotary hammering test

3. EVALUATION METHODS

3.1 Amplitude ratio

To confirm the difference of sound pressure between healthy spots and defective spots, the relationship between maximum input load measured by impulse hammer and maximum sound pressure is investigated. Fig. 1 shows their relationship that obtained from the experiment. From this figure, it can be seen that maximum input load and maximum sound pressure has a linear relationship in healthy spots. On the other hand, sound pressures of defective spots vary widely and they are larger than that of healthy spots. Next, to analyze them quantitatively, amplitude ratio shown in Eq. (1) is used in order to consider the influence of input load variations.

$$\text{Amplitude ratio} = P_{max} / F_{max} \qquad (Pa / N) \tag{1}$$

where P_{max} is the maximum sound pressure, and $F_{\max}$ is the maximum input load. Fig. 2 presents maximum sound pressure data, which directly gain from the experiment. By using the amplitude ratio, sound pressure data can be clearly identified the healthy zone and the defective zone as illustrated in Fig. 3. From Fig. 3, it can be seen that there is an almost continuous transition between healthy spots and defective spots. It is relatively obvious to identify the defective spot using the amplitude ratio of sound pressure; therefore, this method is one of the effective feature quantities of hammering sounds. However, there are several defective areas that have a small amplitude ratio in which they are needed to diagnose using another feature quantity to evaluate the degree of deterioration.

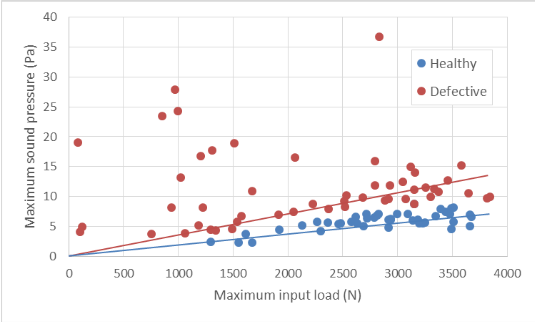

Fig. 1 Input load and sound pressure graph

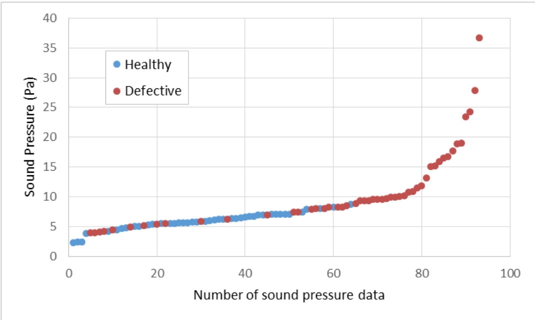

Fig. 2 Maximum sound pressure from an impulse hammer

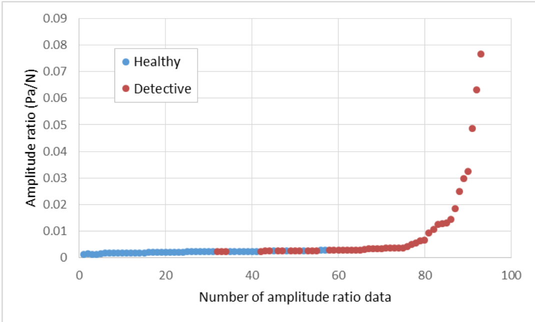

Fig. 3 Analyzed data – Amplitude ratio

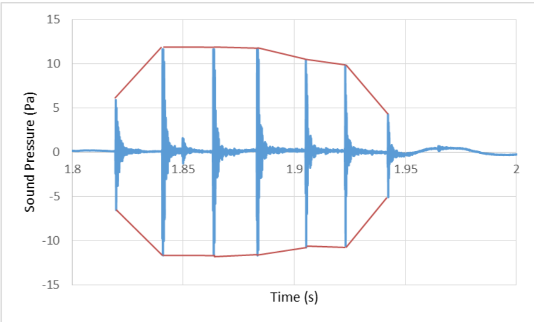

Fig. 4 Time history waveform from rotary hammering test

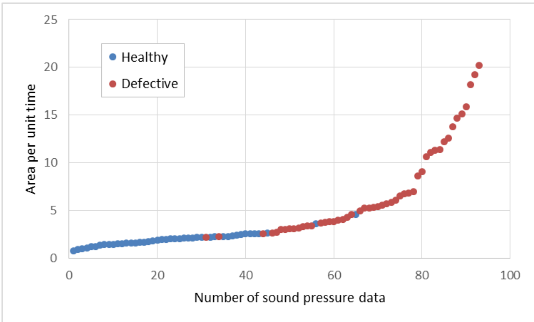

Fig. 5 Maximum sound pressure envelope

3.2 Envelope curve

For rotary hammering test, there is precise load variations due to the collision of polyhedron tip. However, hammering load depends on the rolling velocity, which affects the polyhedron head heavily hits or lightly hits an inspection surface; this causes the inaccuracy of experimental data. Thus, to reduce such a disadvantage, improvements regarding data analysis are conducted by calculated six envelope areas of sound pressure-time history that connects each maximum value of sound pressure as shown in Fig. 4. Finally, an average area of maximum sound pressure per unit time for one period of hammering are obtained. After that, all data of envelope curves are arranged in an ascending order as shown in Fig. 5. From Fig. 5, it can be seen that healthy areas and defective areas are separated at a certain number. By using this envelope curve technique, it is confirmed that the variation of maximum sound pressure of each hammering is effectively reduced. Defective zone and healthy zone can be easily distinguished by the rotary hammering test without load measurement.

4. CONCLUSIONS

In this study, sound pressures of healthy spots and defective spots are measured using different types of hammers, and then compare their detection capabilities. According to the experimental results, we can conclude that the maximum sound pressure envelope (a rotary hammer) and the amplitude ratio (an impulse hammer) can classify healthy and defective zone at almost the same accuracy; however, a rotary hammer is still superior to an impulse hammer since it is more convenient to use in outdoor experiment. In the future, we plan to find the other factors that influence the experimental results and plan to improve rotary hammering sound diagnostic measure regarding some deficient inspection efficiency.