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

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1. INTRODUCTION

Recently, the number of deteriorated reinforced concrete structures is increasing not only in Japan but also all over the world. Therefore, to maintain the existing (aging) structures and to prevent those from unexpected accident become an important issue to civil engineers. Non-destructive testing techniques, including hammering test is the standard method of evaluating the quality of concrete in building or structures without causing damage to structures in which there are a few methods that can conveniently apply in the actual inspecting fields. The hammering test is widely used for detecting defective areas on the aging concrete structures since it can be conducted at low cost, and it is independent of the weather and surrounding environment. However, it requires a certain skill level and experiences to evaluate the defect conditions using the characteristics of hammering sound. There are two types of hammers – impulse hammer and rotary hammer.

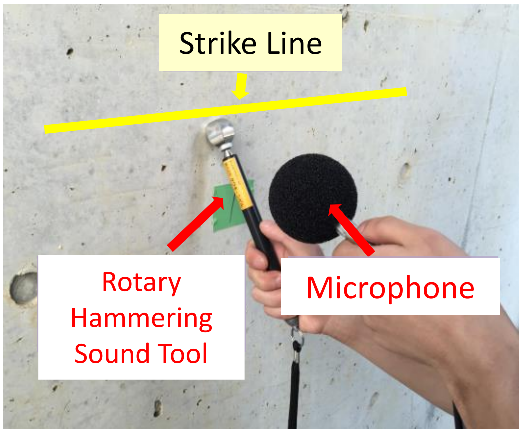

Photo 1 Rotary Hammering Test

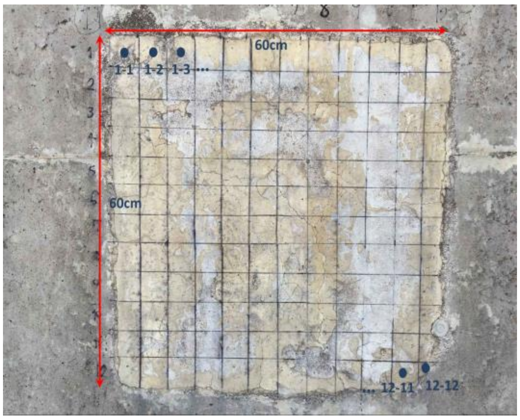

Photo 2 Measuring area and the number of hammering points

2. METHOD

For the evaluation of defect condition, multidimensional information, involving maximum sound pressure, which is the most common factor in the test, frequency spectrum and vibration damping should be applied for diagnosis.

2.1 The Hammering Test

In this study, two types of hammering test are conducted on the existing deteriorated bridge – rotary hammering test and impulse hammering test. As shown in Photo 1, rotary hammering test, a rotary hammer using as an inspection tool has a polyhedron metal attached on the rod tip. During the measurement, we roll the metal against the concrete surface to generate an impact sound and analyze it to gain frequency spectrum. Hammering sound is measured in the square area (60 cm H × 60 cm W) that has crack on the surface. Then, we divide this area into 5cm square and each grid point is set as each hammering point. The hammering points are numbered from 1-1, 1-2 to 12-12 as illustrated in Photo 2. To obtain the exact input load value, impulse hammer shown in Photo 3 is used in the test. The distance of microphone is about 5cm away from the striking point. Hammering sound data are recorded 5 times by 51.2 kHz sampling frequency at each point. The conventional hammering test is inferior to the rotary hammering test except the fact that amplitude ratio can be found from impulse hammer in which it is very useful to estimate the deterioration level.

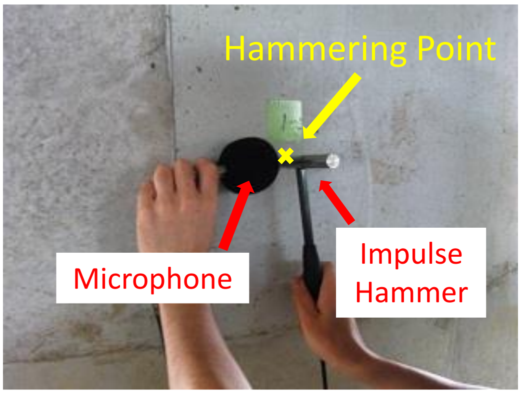

Photo 3 Impulse Hammering Test

2.2 Data Assessment Method

(1) Amplitude ratio

To confirm the difference of sound pressure between healthy spots and defective spots, the relationship between maximum input load and maximum sound pressure by impulse hammer are 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, and sound pressure of defective spots are larger than that of healthy spots. Next, to classify the difference of output amplitude between healthy spots and defective spots, the amplitude ratio shown in

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Eq. (1) is used in order to reduce the input load variations.

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

where $P_{\max}$ is the maximum value of sound pressure, and $F_{\max}$ is the maximum value of input load. By using the amplitude ratio, sound pressure data can be clearly identified the healthy zone and the defective zone as illustrated in Fig. 2. In Fig. 3, it shows an example of time history waveforms of sound pressure obtained from the hammering test. According to the figure, it can be confirmed that the duration of hammering sound and the magnitude of sound pressure at the defective area are much longer and higher than that at the healthy area. These two information is useful in determining the deterioration level of concrete. Although it can be approved that it is possible to reduce variations in input load by the amplitude ratio, the measurement of load as well as sound will be carried out simultaneously, which impair the ease of striking sound methods.

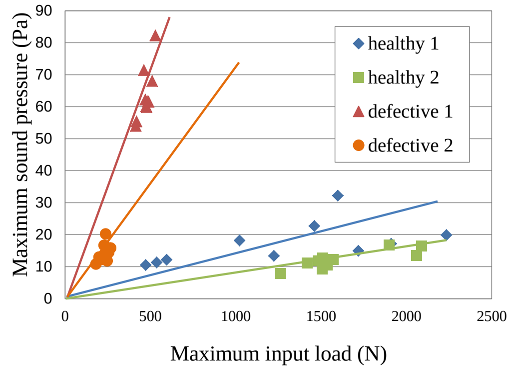

Fig. 1 Relationship between input load and sound pressure

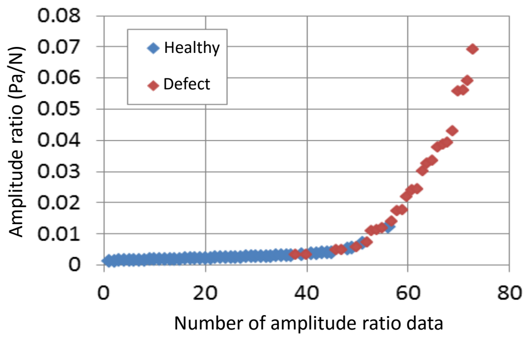

Fig. 2 Amplitude ratio data from impulse hammer

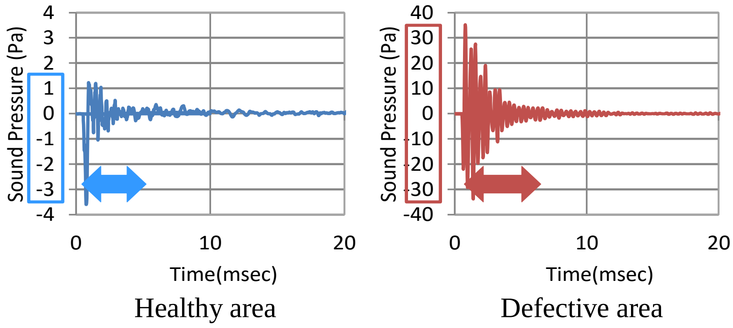

Fig. 3 Example of time history waveform of sound pressure

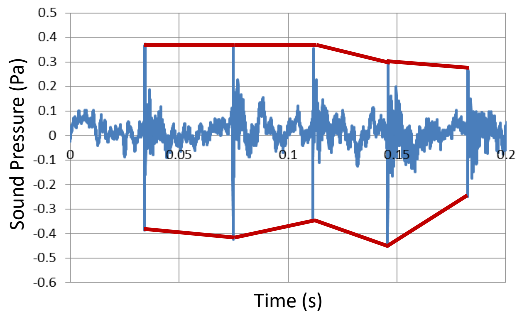

Fig. 4 Time history waveform obtained by rotary hammering test

(2) Envelope curve

In the rotary hammering test, there are variations in the load of collision rolling at the tip. The rotary hammer generates sound when it is rotated and its angled head strikes the inspection target continuously, thus it is very efficient in the inspection work. However, hammering load depends on rolling velocity, which effects the polyhedron head heavily strikes or lightly strikes the inspection surface; this error causes the previous data not accurate. In order to reduce such a disadvantage, research and development regarding hammering test are conducted. Hence the enclosed area of envelope curves (red line) that connect each maximum value of sound pressure waveform is determined as shown in Fig. 4. Five waves with the largest maximum amplitude values are extracted from a group of waves as illustrated in Fig. 4, and these areas give an average area of maximum sound pressure per unit time for one period of hammering. After that arrange all data of average area of envelope curves in the ascending order as presented in Fig. 5. By using the envelope curve technique, it is confirmed that the variation of maximum sound pressure of each hammering is reduced. Moreover, defective zone, cracking zone and healthy zone can be easily distinguished.

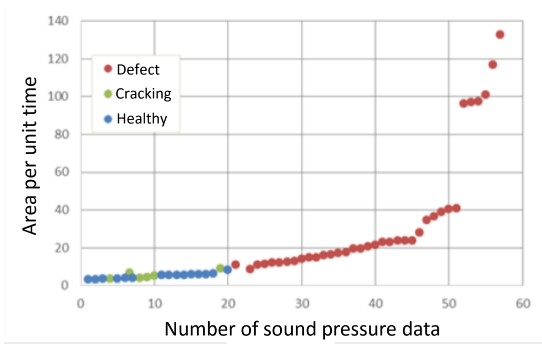

Fig. 5 Maximum sound pressure envelope from rotary hammer

3. CONCLUSION

In this study, we conduct impulse hammering test and rotary hammering test, and compare their detection capability. From this study, we can conclude that the amplitude ratio analyzed from impulse hammer is more accurate than the maximum sound pressure envelope analyzed from rotary hammer; nevertheless, both data can detect the deterioration level of concrete structure. In the future, we plan to improve rotary hammering sound diagnostic measure due to its deficient inspection efficiency.