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Fundamental study for long-distance noncontact shallow underground exploration technology by acoustic irradiation induced vibration

音波照射加振による遠距離非接触浅層地中探査技術のための基礎検討

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1. Introduction

The noncontact acoustic inspection (NCAI) method using acoustic irradiation induced vibration and laser Doppler vibrometer (LDV) can detect crack defects near the surface of concrete structures even from a distance of 20 m or more. We have already clarified the effectiveness of this method in actual bridges and large underground caverns (shotcrete)[1-4]. On the other hand, there is a problem of angle dependence of the sound source that it becomes difficult to excite the flexural resonance phenomenon when the sound wave is applied obliquely to the surface to be measured (usually 30 degrees or more). In addition, when a sound wave is emitted from a long distance, a large sound source is required, which causes a problem that environmental noise cannot be avoided. However, if sound waves can be emitted from an unmanned aerial vehicle (UAV) that has become easy to use in recent years, a small sound source that can be mounted on the UAV is used because it can approach the measurement target surface. This makes it possible to solve the problems of angle dependence and environmental noise at the same time. Therefore, we conducted a basic study using a sound source-mounted UAV and an outer wall tile specimen, and clarified that it is possible to actually inspect the outer wall tile by applying acoustic wave irradiation from the UAV[5]. This means that in this method, the sound source position can be set freely by using UAV, and it has an extremely wide range of application.

On the other hand, as methods for exploring the shallow underground, radar exploration, magnetic exploration, electrical exploration and elastic wave exploration are mainly used. However, it is difficult to carry out noncontact exploration from a long distance because all the methods need to bring the measuring equipment into contact with or close to the ground surface. However, in the NCAI method using sound wave irradiation excitation from the UAV as described above, it is sufficient if the vibration velocity distribution on the measurement surface can be measured. Therefore, even if there is a separation of more than 10 m, there is a possibility that shallow geological survey can be performed without contact. Therefore, this time, we conducted a fundamental technical study on whether or not shallow underground exploration is possible by acoustic irradiation induced vibration, with the sound source fixed on the table.

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2. Experimental Setup

A basic verification experiment of shallow underground exploration by acoustic irradiation induced vibration was performed on a hollow circular container buried in a small sand tank (500 × 500 × 300 mm^3, filled with silica sand No. 7). The experimental setup is shown in **Fig.1**. As the soil, silica sand No. 7 (particle size range of about 0.05 mm to 0.3 mm), which is considered to have a relatively uniform particle size distribution, was used with emphasis on the reproducibility of the experiment. The commercially available circular

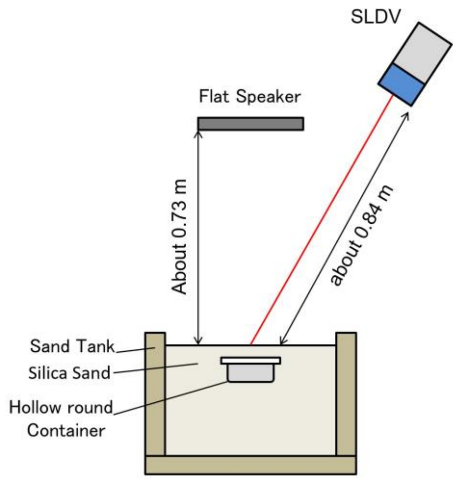

Fig.1. Basic setup of noncontact acoustic exploration method using acoustic irradiation induced vibration and laser Doppler vibrometer.

containers used as buried objects had diameters of 100 mm and 160 mm and weights of 52.8 g and 115.8 g, respectively (lid: polyethylene, body: stainless steel). Curing tape is applied from the edge of the lid to the side surface of the main body so that the lid does not come off due to the sand pressure. After placing the buried object in the small sand tank, the sand bag (about 26 kg) was pressed for about 24 hours from the day before the measurement. Pressurization is performed by placing a wooden board on silica sand and placing a sandbag for pressing on it. A flat speaker (FPS Corp., FPS2030M3P1R) was used as the sound source, and a scanning vibrometer (SLDV: Scanning LDV, Polytec Corp., PSV400-H4) was used as the LDV. The distance from the silica sand surface to each device was about 732 mm and about 836 mm, respectively.

3. Experimental Result

Fig.2 shows the vibration velocity distribution (149 Hz) around a circular container with a diameter of 100 mm (depth 50 mm) when irradiated with sound waves in the frequency range 100 Hz to 1 kHz. The number of measurement points is 121 (11 × 11 points), and the measurement point interval is about 22 mm in length and width. The white line circles indicate the position and size of the buried object (100 mm in this case). The white line circles indicate the position and size of the buried object (100 mm in this case). From this figure, it can be confirmed that the vibration speed is higher on the buried object than on the surroundings. Note that this image example is an image of an SLDV CCD camera installed slightly diagonally to the sand tank, so the detection position of the embedded object is slightly lower than the center of the screen. Note that this image example is an image of an SLDV CCD camera installed slightly diagonally to the sand tank, so the detection position of the embedded object is slightly lower than the center of the screen.

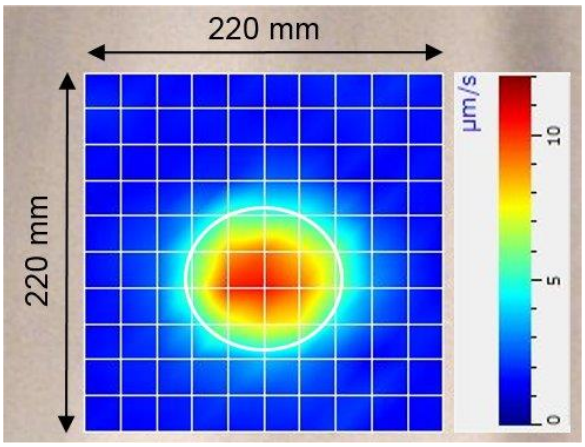

Fig.2. Vibration velocity distribution (149 Hz, hollow circular container (diameter 100 mm, depth 50 mm)).

Tables 1 and **2** show changes in the detection frequency when the size and depth of the buried object are changed. From the table, it was confirmed that the detection frequency changes in inverse proportion to the size of the buried object. On the other hand, the detected frequency did not change much even if the depth of the buried object was changed, which means that the observed phenomenon is not the flexural resonance but the vibration of the container itself in the buried state.

Table 1 Size and detection frequency of buried objects(Depth 50 mm).

Diameter	Detected Freq.
100 mmφ	149 Hz
160 mmφ	110 Hz

Table 2 Depth of buried object and detection frequency(dia. 100mm).

Depth	Detected Freq.
50 mm	149 Hz
100 mm	167 Hz
150 mm	167 Hz

4. Conclusion

From the results of this fundamental study, it was confirmed that it is possible to carry out shallow underground exploration by acoustic irradiation induced vibration. Therefore, in the future, we plan to study the case of using various soils and the case of actually mounting a sound source on the UAV.

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