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Distinguish the Buried Objects of Extremely Shallow Underground by Frequency Response Using Scanning Laser Doppler Vibrometer

スキャニングレーザドップラ振動計を用いた周波数応答による極浅層地中埋設物の識別

Touma Abe[1‡], Tsuneyoshi Sugimoto[1] ([1]Facult. Eng., Toin Univ. of Yokohama)
阿部冬真 [1‡], 杉本恒美 [1] ([1]桐蔭横浜大 工)

1. Introduction

A sound wave vibration and a Scanning Laser Doppler Vibrometer (SLDV) are used for a method of exploring and imaging an extremely shallow underground (1) (2). The target is mainly a plastic antipersonnel land mine. Therefore, the exploration depth is assumed to be about 10 cm. In our previous study, we confirmed that a buried object showed a response range of specific frequency (2). This time, plastic containers, a hollow steel can, a stone and an unglazed pot are used in the experiment. We propose a method of distinguishing those buried objects using the response range of the frequency corresponding to a vibration velocity.

2. Experiment Method Using SLDV

2.1 Outline of Experiment

The fundamental concept of the exploration method using the SLDV (Polytec Corp, PSV400-H8) is shown in **Fig. 1**. SLDV measures the vibration of ground surface excited by sound wave caused from vibratory source. The vertical direction vibration of the ground surface is measured by SLDV. The acoustic impedance of a buried object is distinctly different from that of the soil used as the propagation medium. Therefore, the buried object affects the propagation of vibration in the soil. This effect can be detected on the ground surface if there is the buried object near the ground surface. This time, two flat speakers (FPS Corp, 2030M3P1R) that have a sharp directivity are used for a vibration source. To generate a slow wave (3), flat speakers are inclined by about 20° (4).

2.2 Experimental Setup

The sand tank (110 × 135 × 50 cm^3) in the laboratory that had been filled with sand of uniform particle size (200 to 300 μm) was used for this experiment. The experiment setup is shown in **Fig. 2**. Plastic containers (11 × 11 × 6 cm^3, hollow: 80g, filled with sand: 825g, and filled with sugar: 540g), the hollow steel can (dia. 8.5 × 8 cm^3, 70g), the stone (5.5 × 6.5 × 2.7 cm^3, 210g) and the unglazed pot (top dia. 12 × 4 × bottom dia. 4 cm^3, 225g) are used as a buried object. The unglazed pot was buried upside down. Buried objects are shown in **Fig. 3**. The depth of buried objects is 2 cm. Output wave was the white noise, and output time was one second.

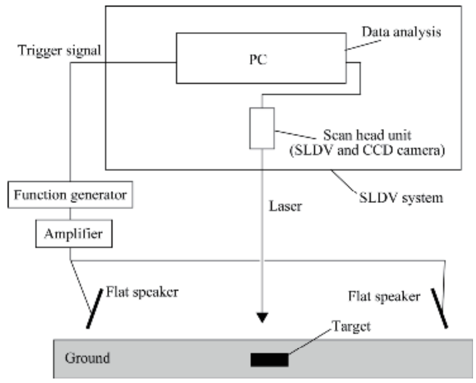

Fig. 1 Fundamental concept of exploration method using SLDV

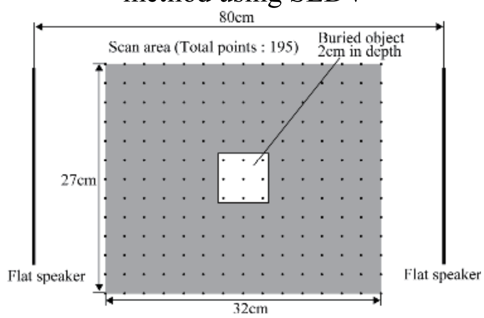

Fig. 2 Experiment setup

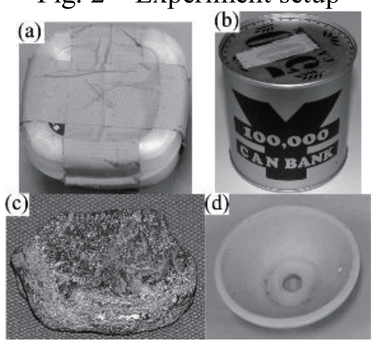

Fig. 3 Buried objects
(a) Plastic container (b) Hollow steel can
(c) Stone (d) Unglazed pot

kaosunetto@gmail.com

3. Confirmation of Frequency Response Range of Buried Objects

3.1 Standardization of Frequency Response Range

The vibration velocities corresponding to frequency on and around points of the buried position are compared and it is standardized. The vibration velocity is standardized by the following equation.

$$A(\omega) = 1 - \frac{G(\omega)}{F(\omega)}$$

A(ω) is a standardized vibration velocity. F(ω) is the vibration velocity corresponding to frequency on the buried position, G(ω) is a vibration velocity corresponding to frequency around the buried position. Frequencies are shown on the brightness image when A(ω) is more than the half value (0.5) of the maximal value (1). Examples of the results are shown in **Fig. 4**. Figure 4(a) is average result of several points by the on and around points of the buried position. Figure 4(b) is a result of standardization of Fig. 4(a). The strong responses of the frequency are used as a brightness imaging when the vibration velocity of this standardization result is more than the half value.

3.2 Brightness Imaging of Frequency Response Range

The brightness imaging results after standardization of each buried objects are shown in **Fig. 5**. The response ranges of the frequency of the hollow plastic container and the plastic container filled with sand are shown at 100 to 200Hz. The response range of plastic container filled with sugar is shown at 150 to 250 Hz. This result is near the response range of the hollow steel can. On the other hand, the response range of the stone is shown at 1050 to 1100 Hz and 1200 to 1300 Hz and the unglazed pot is about 1000 Hz. Results of the stone and the unglazed pot is distinctly different than result of other buried objects. Therefore, it is thought that the density and the size affect the response range of the frequency of the buried object.

4. Conclusion

We confirmed the response range of the frequency of each buried objects. It was possible to distinguish the buried objects by using the brightness image of the frequency response. It is thought that the difference of the frequency response range of each buried objects are done by the density and the size. As a future task, the response range of the frequency of woods and metals will be confirmed. Besides, based on these data, a new method of identifying buried objects will be developed.

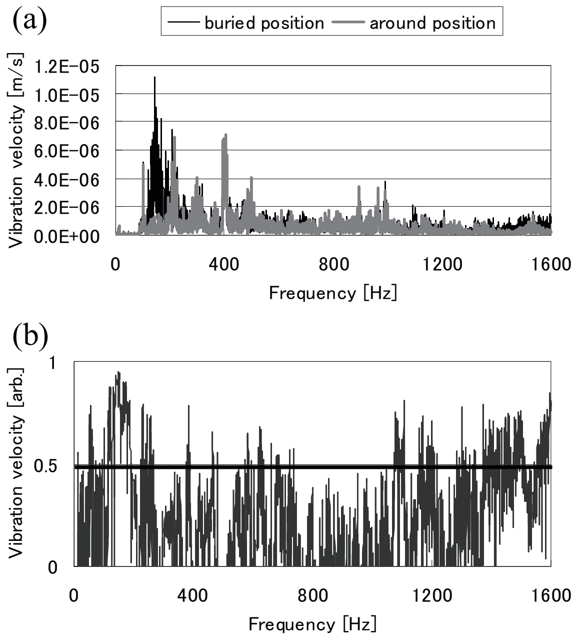

Fig. 4 Vibration velocity vs. frequency
(a) Comparison between the buried position and around position
(b) Standardization result

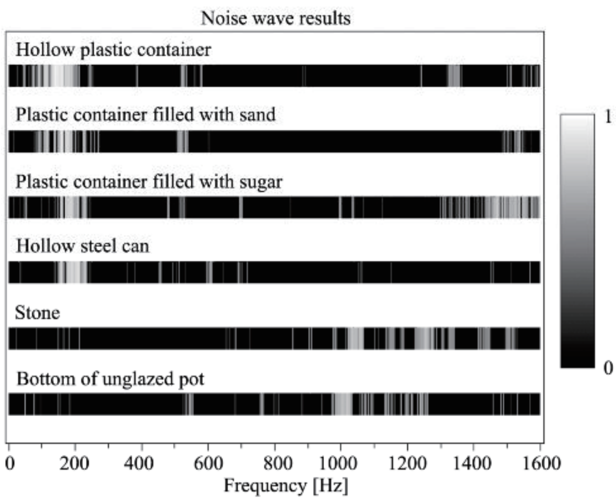

Fig. 5 Brightness images of the frequency response range

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