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Water distribution measurement in sand using sound vibration and SLDV

T. Sugimoto[a], Y. Nakagawa[a], T. Shirakawa[a], M. Sano[a], M. Ohaba[b] and S. Shibusawa[b]

[a]Toin Univ. of Yokohama, 1614, Kurogane-cho, Aoba-ku, 225-8503 Yokohama, Japan
[b]Tokyo Univ. of Agriculture and Technology, 3-5-8, Saiwai-cho, 183-8509 Fuchu, Japan
tsugimot@cc.toin.ac.jp

This time, we propose a method of monitoring and imaging of the water distribution in the plants of rooting zones using sound vibration and scanning laser Doppler vibrometer. In this experiment, we measured the temporal change of the water distribution in the soil. A giant magnetostrictive vibrator is used as a sound source. SLDV measures the vibration of ground surface. The propagation velocity between vibrator and measuring point is used to estimate the water distribution. Also, the soil-water sensor which measures the water quantity of the soil using the electric permittivity is installed in the soil. From the experimental results of the vibration measurement and electrical detection, we confirmed the effectiveness of our measuring method.

1 Introduction

In recent years, the increase of the population of the world doesn't stop and the United Nations is reporting that the population of the world exceeds seven billion. Also, the abnormal weather occurs in the world each place. By these things, a serious water shortage is caused in a lot of countries. In the purpose of using water, there are daily life water, industrial water and agricultural water. Agricultural water is using about 70 % of all water. Therefore, many studies about the saving of the agricultural water are performed. The irrigation system using the difference of soil water potential as one of the researches attracts attention[1-2]. This method has the nature to keep water content inside ground constant. However, effective saving water is not able to be performed, because the water distribution in soil is difficult to grasp. Although the electrical detection method and the pF meter are used for the measurement method of water in ground, measuring area of a sensor is very small. Therefore, we propose a method of monitoring and imaging of the water content in the plants of rooting zones using a sound vibration and the scanning laser Doppler vibrometer (SLDV; Polytec Corp, PSV400-H4). Our method is possible to measure a wide area[3-8]. The underground exploration which used a sound vibration is already done[9-11]. However, the research which controls Irrigation by measuring the water distribution of the plants of rooting zones using the sound vibration isn't done. This time, we study about the influence to the propagation velocity when changing the volume water content of the water distribution.

2 The Principle of Measurement of the Water distribution

2.1 The method of measuring

The schematic figure for water distribution measurement using SLDV and giant magnetostrictive vibrator is shown in Fig.1. SLDV measures the vibration of ground surface excited by sound wave caused from vibration source. Using the vibration waveform and the output waveform calculates the propagation velocity from vibration source to the measurement point. There is a difference in the average of propagation velocity (sand: about 130 m/s, water: about 1500 m/s) in sand and water. When passing water distribution, the propagation velocity is expected to be fast. On the basis of this supposition, water distribution can be estimates.

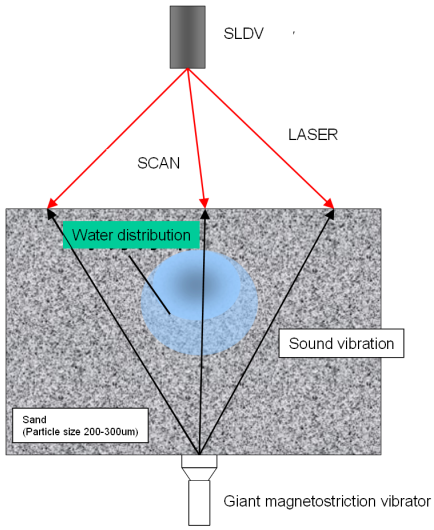

Fig. 1: The schematic figure for water distribution measurement.

2.2 The principle of calculation of the propagation velocity

The calculation method of the propagation velocity is shown next. The propagation time and the propagated-distance are necessary to calculate a propagation velocity. It calculates a propagation time using the Hilbert transform. The propagated-distance is a distance from the sound source to the measuring point. Calculation example is shown in Fig.2. First, it looks for the envelope using Hilbert transform. After that, it calculates the time which is taken for the threshold value to the envelope. This time, the difference with the time which was calculated from the output waveform and the vibration waveform is propagation time.

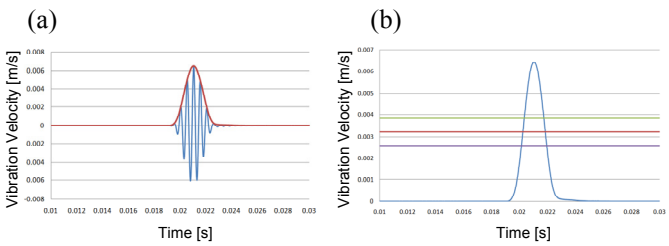

Fig. 2: Examples of the calculation process. a) Hilbert transforms (b) The envelope and the threshold value.

2.3 Volume water content

The volume water content is one of the ways to show the water quantity of ground. In this time, we measured the volume water content by two measuring methods. One is measured by soil water sensor (ECH2O probe: decagon device Inc, EC-5) and the other method is measurement of the water-ratio with the soil sample (soil sample method). In this method, the volume water content is computed by

multiplying the water-ratio by the true specific gravity of sand after vibration measurement is ended. The true specific gravity of sand is using 2.68 g/cm^3.

2.4 The Relationship between the propagation velocity and the volume water content

We confirmed whether the volume water content and the propagation velocity are proportional. Figure 3 shows an experimental setup. Experiment method is shown as follows. The giant magnetostrictive vibrator sends vibration from the base of sand which the about 5 cm thickness was wetted and the acceleration sensor that installed in the surface of the sand measures the vibration waveform. After that, we calculate the propagation velocity. A result is shown in Fig.4. From this result, we confirmed that the propagation velocity became fast according to the volume water content.

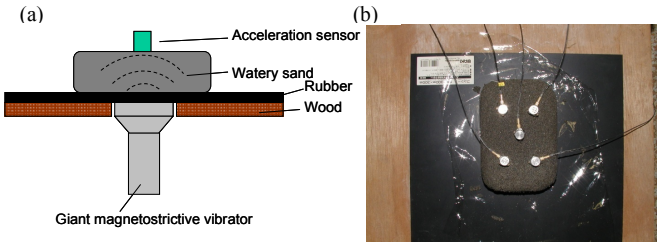

Fig. 3: Experimental setup (The size of the watery soil 10 × 15 × 7 cm^3) (a) Experimental setup (b) The installing position of the acceleration sensors.

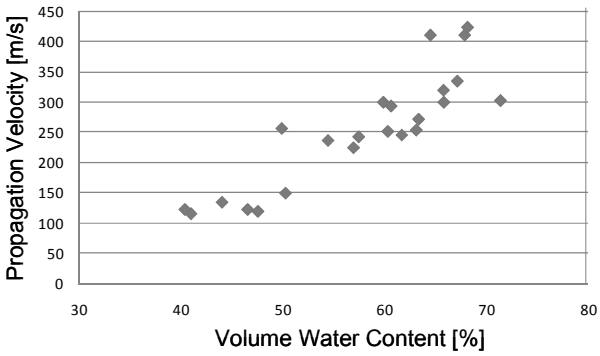

Fig. 4: Experimental setup (The size of the watery soil 10 × 15 × 7 cm^3) (a) Experimental setup (b) The installing position of the acceleration sensors.

3 The Experiment of the Measurement of the Water Distribution

3.1 Experiment when changing the water content near the sand surface

3.1.1 Experimental setup

Figure 5 shows an experimental setup (The side view of the sand tank). There are nine holes to set up the sound source which was covered with the rubber in the sand tank base. It sends vibration with the giant magnetostrictive vibrator to have installed in the hole of the sand tank base. SLDV measures the vibration of ground surface excited by sound wave caused from vibratory source. The plastic container (40×50×30 cm) which is made from acrylic in the laboratory that had been filled with sand of uniform particle size (200 to 300 μm) was used for this experiment. In this experiment, it measures the status of the water distribution by the change of the vibration propagation. The making method of the water distribution is shown below. First, the plastic container is filled with the sand into the plastic container. Next, the water of the fixed quantity is pour into the container. Finally, a plastic container is removed after having put it in the sand tank upside down. This time, we study that there was a difference in the propagation velocity, when the water-content of the water distribution is 150 ml and 250 ml. Water distribution is installed on the surface of the sand tank and it measured. Experiment method is shown as follows. The output waveform uses the burst wave of 2 kHz of sine wave, 3 cycles. The scan area of SLDV is 17×23 points, the point interval are about 1.75 cm wide and about 1.8 cm long.

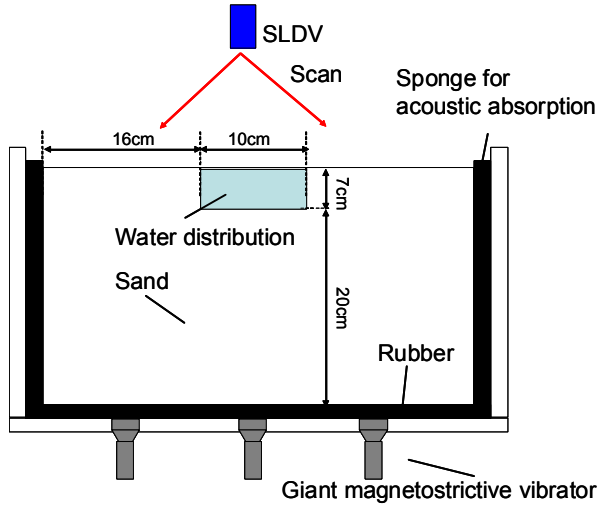

Fig. 5: Experimental setup when installing water distribution in the sand surface.

3.1.2 The experiment result

Result of imaging in the speed of sound range common sound-velocity distribution from 150 m/s to 180 m/s is shown in Fig.6. From this figure, we can confirm that the propagation velocity of 250 ml is faster than 150 ml. The relation between the volume water content and the propagation velocity which was created by using soil sample method and the vibration measurement data of 150 ml, 250 ml is shown in Fig.7. We find that there is a difference between distribution of 150 ml and 250 ml from this figure. We think that the water-content of the water distribution in ground can be estimated by the non-contact using the difference of such a propagation velocity.

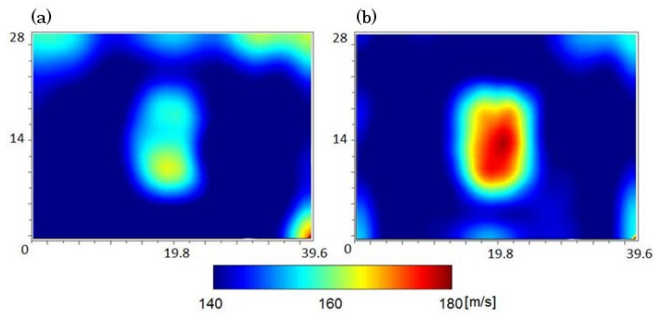

Fig. 6: Result of imaging of sound velocity distribution. (a)150 ml (b)250 ml

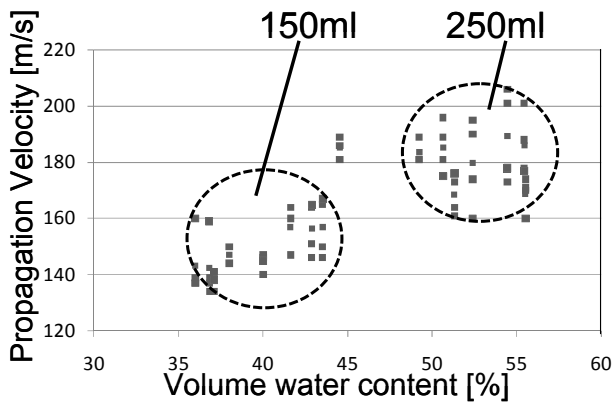

Fig. 7: The volume water content and the propagation velocity.

3.2 Water distribution imaging experiment using negative pressure difference irrigation system

3.2.1 Experimental Setup

Figure 8 shows an experimental setup when using negative pressure irrigation system. The porous pipe which is made from ceramic is installed in the about 18 cm height from the sand tank base and the level control tank is installed in the position with the low of about 20 cm from the height of the porous pipe. The rate of the water which is supplied to ground by this height is decided. The method of experimenting is same as the method of experimenting to the above. However, this time, the measurement time must be made short because to measure temporally changing water distribution. Therefore, using the sound source position is only under the porous pipe. The vibration measurement measured in the interval of 10 minutes and measured until 90 minutes.

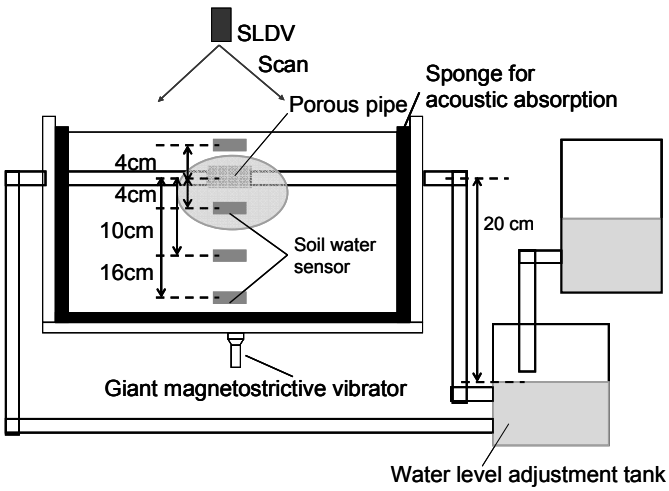

Fig. 8: Experimental setup when using negative pressure irrigation system.

3.2.2 The experiment result

A result of imaging in each time is shown in Fig.9. From this figure, we can confirm that water distribution is temporally changed. Also, a graph with the volume water content which was measured by the soil-water sensor is shown in Fig.10. The graph of average with the volume water content which measured by four sensors and the graph of the average with the propagation velocity which was measured at nine points of the near the porous pipe is shown in Fig11. We think that the water distribution reaches a base in this time zone because the value isn't changing about 40 minutes later after beginning in the measurement from Fig.11. At the same time, the value isn't changing in the approximately similar time zone about the propagation velocity, too. In other words, we can confirm that the influence to the propagation velocity when changing the volume water content of the water distribution.

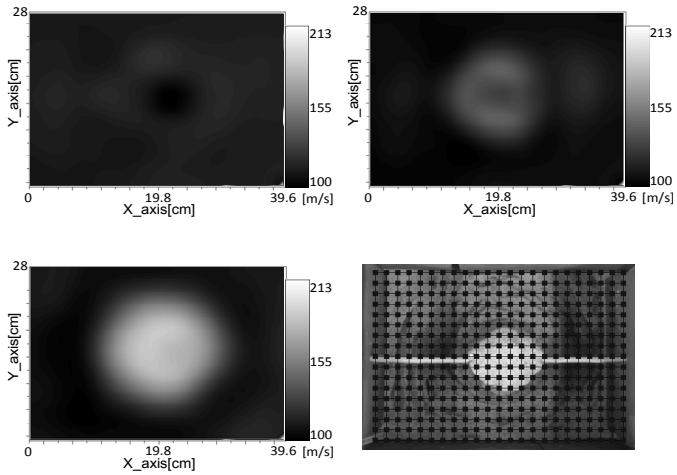

Fig. 9: The results of imaging of sound velocity distribution in each time. (a) 10minutes (b) 20minutes (c) 40minutes (d) Scan area by CCD camera

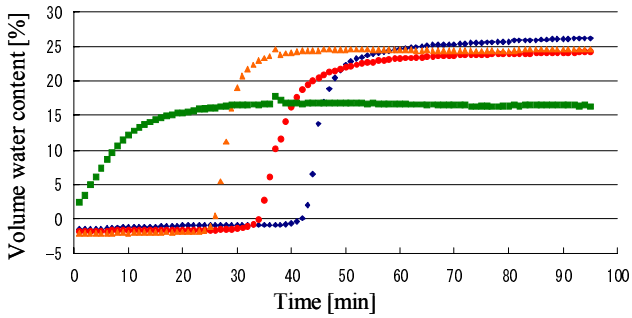

Fig.10: Experimental result of the volume water content which measured by four sensors. Green square:4cm, Orange triangle:4cm, Red circule:10cm, Blue diamond:16cm

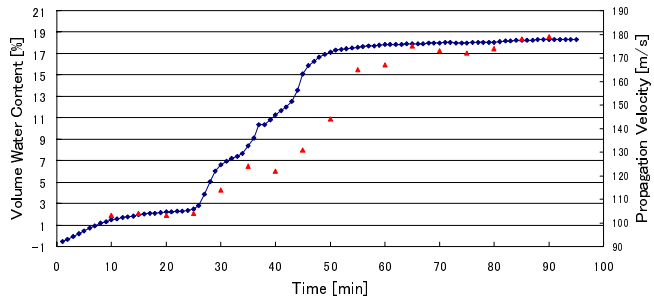

Fig.11: Experimental result of the volume water content and the propagation velocity. Blue diamond: Volume water content [%] , Red triangle: Propagation velocity [m/s]

4 Conclusions

This time, we can confirm that the used vibration velocity distribution image was a very effective imaging method to the water distribution which is in the shallow position near the ground surface. Also, in the experiment which used negative pressure irrigation, we can confirm

that it was caught in the water distribution which changes time wise by measuring at both of the vibration measurement. In the future, we plan to review the improvement of the estimated precision of the volume water content by the vibration measurement. And, we intend to examine whether our method can apply even in the case that a plant is growing up in soil for gardening.

Acknowledgments

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