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Improved Measurement of Soil Moisture and Groundwater Level Using Ultrasonic Waves

超音波を用いた土中水分水位計測システムの改良

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1. Introduction

Slope failures due to heavy rainfall have frequently occured in Japan. In order to reduce such the damages, monitoring method of soil moisture and groundwater level is important. We developed a monitoring device for soil moisture and groundwater level using ultrasonic waves[1)]. Since this measurement is greatly influenced by temperature, it is necessary to correct this effect. Dummy pair system using two ultrasonic detectors was examined previously for correction of temperature-dependent characteristics[1)]. In this paper, we propose a new temperature correction method using one ultrasonic detector and evalute its usefulness.

2. Ultrasonic Measuring Method

Fig. 1 shows the setup of ultrasonic detector. The wave guide pipe is inserted into the ground and the ultrasonic transducer of 40kHz is fixed on to the upper part. Measurement at various depth can be made by changing the length of this wave guide pipe. The ultrasonic waves generated by the ultrasonic transducer are transmitted in the pipe, reflect at the soil surface of the measuring point and return to the transducer. Soil moisture and groundwater level are measured by the intensity and the propagation time of the reflected waves.

Fig. 2 shows the reflective waveforms at three different states of the soil. At the dry state, reflected waves scatter at rough soil surface and the reflective intensity is small. At the wet state, a water film is formed among the soil particles which make the soil surface smooth. Hence, the scattering decreases and the reflective intensity becomes large. At the saturated state, the groundwater level goes up inside the wave guide pipe, and the propagation time decreases.

We measure a soil moisture by the reflective intensity and the groundwater level by propagation time. Both measurements can be made using one set of the ultrasonic detector.

3. Correction of Temperature-dependent Characteristics

The reflective intensity depends on temperature. To correct the temperature-dependent intensity and propagation time, we proposed the dummy pair system using two ultrasonic detectors. One ultrasonic detector (“soil monitoring detector”) is used for soil monitoring and the other (“temperature monitoring detector”) is used for temperature monitoring. The later one is closed at the lower end of the pipe. The waveform of the soil monitoring detector is influenced both by temperature and moisture, while the waveform of the temperature monitoring detector is only influenced by temperature. In order to correct the values including temperature dependence, a value measured by the soil monitoring detector is divided

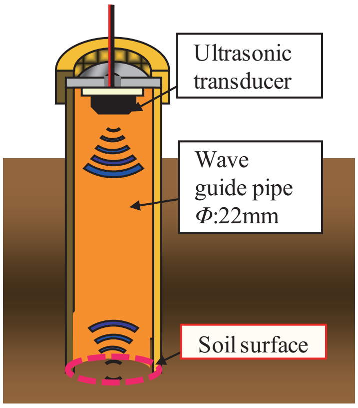
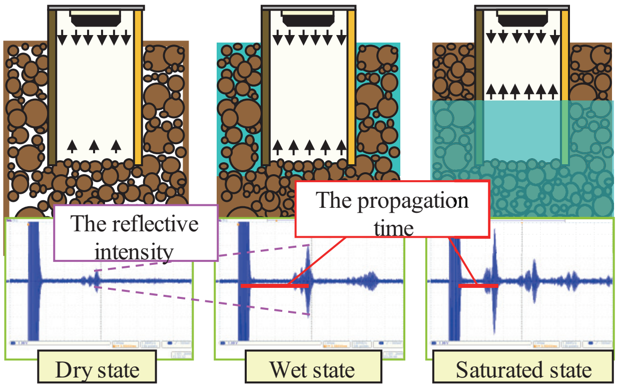


Fig. 1 Ultrasonic detector setup



Dry state　Wet state　Saturated state

Fig. 2 Waveforms at three soil states

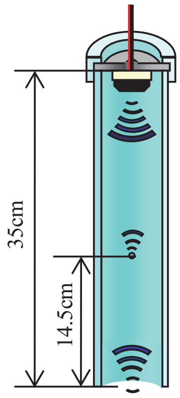


Fig.3 New Correction detector

by a value of the temperature monitoring detector.

However, the dummy pair system requires improvement because of the following points; 1) the environmental conditions of two ultrasonic detections are not completely the same, 2) two ultrasonic transducers do not have the same temperature characteristic, and 3) two ultrasonic detections cost twice to set up. In order to overcome these problems, we proposed the new correction method.

The new correction detector is schematically shown in **Fig. 3**. A needle was inserted through of the wave guide pipe. The reflections from this needle and the soil surface at the measurement point were used to correct temperature-dependent value. This needle was made by aluminum of 1.5mm in diameter. Needle position was set so that the higher order reflections from the needle do not disturb the waveforme of the soil surface measurement. **Fig. 4** shows the waveform obtained by this detecter. Two reflection peaks that are reflected by the needle and the soil surface appear. As the needle reflection is not influenced by moisture at the soil surface, it only changes with the influence of temperature. That is, the needle corresponds to the temperature monitoring detector in the dummy pair system. Then, in order to correct temperature-dependent values, the measured value at soil surface is divided by the measured value obtaind from the needle. The needle system used only one ultrasonic detector and overcame the problem in the dummy pair system.

Fig. 5 shows the indoor experimental setup, and **Fig. 6** shows the experimental results. The reflective intensities both by the needle and by the soil surface increased with the influence of temperature after 4.5 hours. However, the corrected intensity was not influenced by temperature. This change of reflective intensity looks like that of the volumetric water content by a permittivity soil-moisture sensor "EC-5" measured for comparison. The propagation time decreased with the rise of groundwater level after rainfall. Therefore, the groundwater level can be measured by the propagation time.

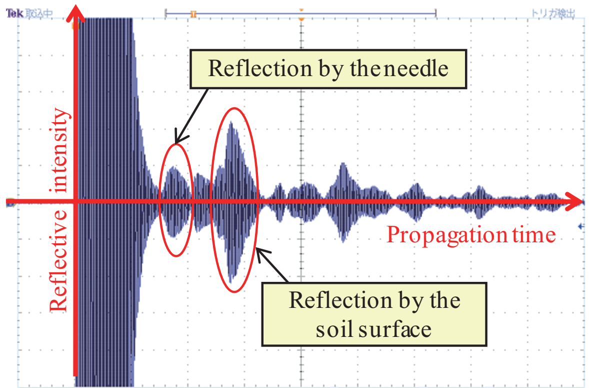


Fig. 4 Reflected waveform

4. Conclusions

The usefulness of new correction method using the needle has been confirmed through out this paper. We will investigate the effects of the shape and thickness of a needle and a long-range outdoor experiment.

Acknowledgment

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Reference

1. K. Tanaka, et al.: Jpn. J. Appl. Phys. 48 (2009) 09KD12.

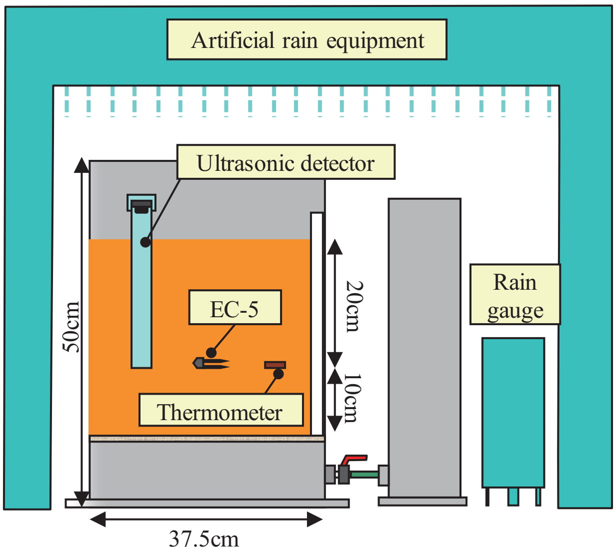

Fig. 5 Experimental outline

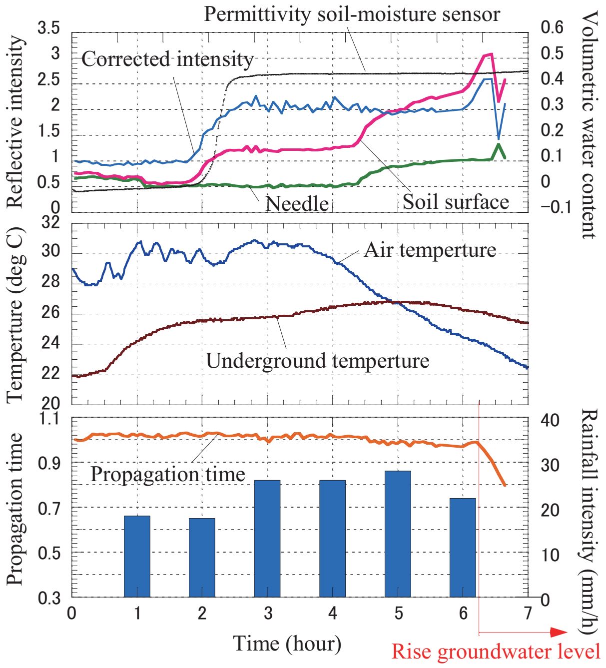

Fig. 6 Experimental results