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Field Monitoring of Soil Moist State and Groundwater Level using Ultrasonic Waves
超音波を用いた土壌水分状態・地下水位の屋外モニタリング

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1. Introduction

There have been a lot of slope failures due to heavy rainfall in Japan, and a lot of lives and infrastructures have been damaged. Therefore, it is important to construct a warning system for detecting possiple slope failures due to rainfall. It has been qualitatively stated that slope failures due to rainfall are mainly caused by an increase in soil mass weight, a decrease in shear strength as a result of increased water content, and a rise in groundwater level.

Various water content monitoring methods that use tensiometers or permittivity soil moisture sensors have already been suggested. However, a tensiometer needs frequent maintenance to supply water. Also, the salinity level in the water influences the permittivity sensor, and it is difficult to install it without changing the state of the on-site soil.

Our group proposed a method that uses ultrasonic waves to monitor both the soil moist state and groundwater level, and we investigated its availability by conducting an indoor soil tank test. It can be easily installed underground and requires minimal maintenance. For this paper, we applied this method to field monitoring.

2. Basic Consideration and verification

Figure 1 shows an ultrasonic detector setup. The detector consists of a transducer and a waveguide pipe. The ultrasonic transducer is installed at the top end of the pipe. The pipe is installed into specific monitoring points and its bottom end touches the underground soil. An ultrasonic wave generated by the transducer travels down the waveguide pipe. Then, it is reflected at the soil surface and returns back to the transducer.

We measured the intensity and propagation time of reflected waves using this ultrasonic detector. The intensity of the reflected waves changes with the moisture in the soil based on a scattering effect. Propagation time is commonly used for measuring distance. So, we can calculate the groundwater level using the propagation time. **Figure 2** shows the waveforms of three soil states (dry, wet, and saturated). In the wet state (Fig. 2(b)), the reflective intensity is bigger than in the dry state (Fig. 2(a)). The difference between Figs. 2(b) and 2(c) is that the propagation time is shorter when the groundwater level rises.

In our previous researches [1), 2)], the intensity of the reflected waves dramatically increased with the change from the dry state to the wet state, and the propagation time decreased with the rise in groundwater level.

3. Monitoring System

Figure 3 is a schematic diagram of the field monitoring system. Several detectors are installed into the ground (**Fig. 4**). A mltiplexer automatically

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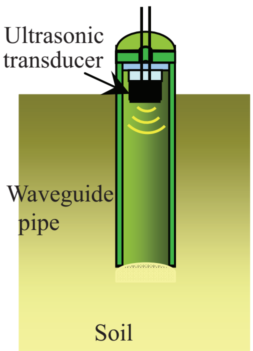
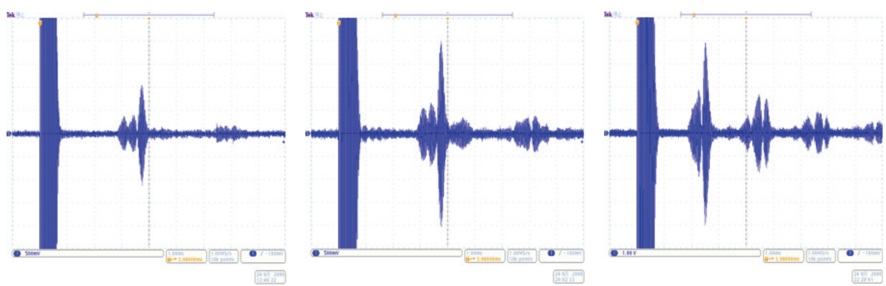


Fig. 1 Ultrasonic detector setup



(a) Dry state (b) Wet state (c) Saturated state

Fig. 2 Waveforms of three soil states

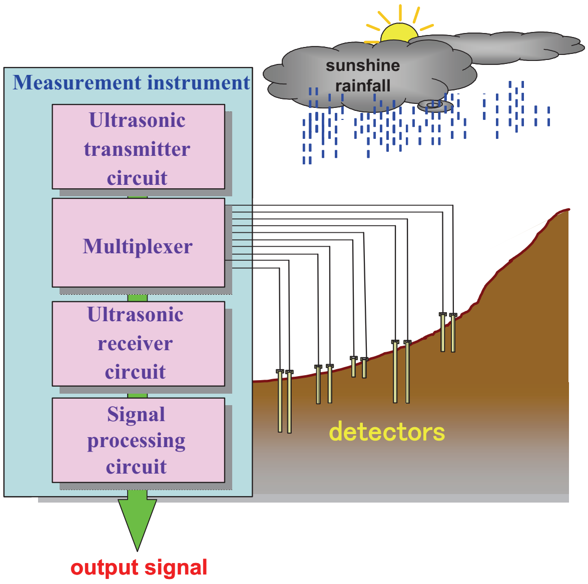


Fig. 3 Schematic diagram of field monitoring system.

Fig. 4 Installation of detectors into ground

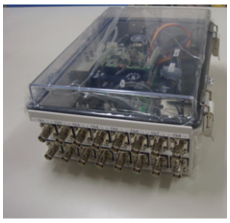


Fig. 5 Measurement instrument

regularly switches these detectors. The signal processing circuit calculates the peak intensity and propagation time of the received signals. The measuring instrument (Umeda Electric Co., Ltd.) shown in **Fig. 5** contains these four functions.

For outdoor monitoring, we have to take into account the temperature characteristics of the transducers. Therefore, we used two detectors. One detector was for the monitoring soil and another was for calibrating the characteristics based on the temperature and other climate factors. The bottom end of the calibration pipe is sealed and soil was packed into the pipe until the height of 1-2 cm. The temperatures of both detectors were treated as equal when they were installed close to each other in the

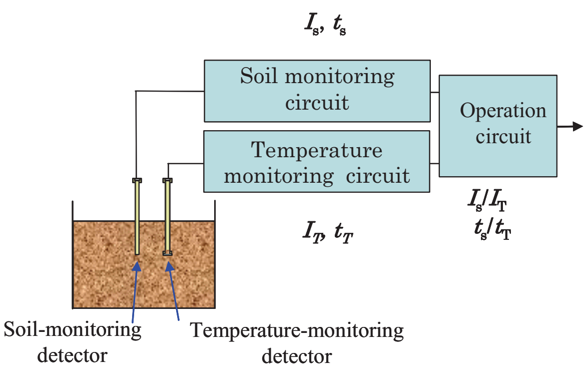


Fig. 6 Calibration of temperature characteristics

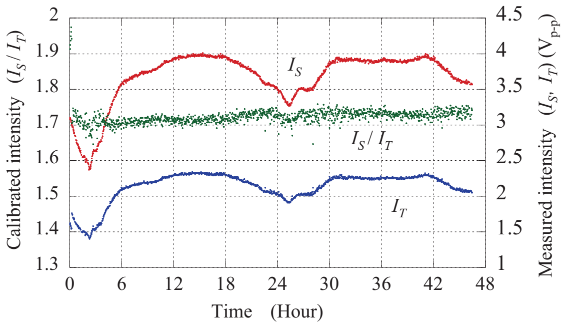


Fig. 7 Calibration results

ground. The calibration system is shown in **Fig. 6**. The soil-monitoring detector measured the intensity, I_s, and the propagation time, t_s, of the reflected waves. The temperature-monitoring detector also measured the intensity, I_T, and the propagation time, t_T, of the reflected waves. We calibrated the intensity and the propagation time by calculating I_s / I_T and t_s / t_T.

We used a MA40E8-2 waterproof transducer (ultrasonic transmitter-receiver made by Murata Manufacturing Co., Ltd) and transmitted a burst wave of 40 kHz.

4. Results

Figure 7 shows the calibration results. I_s and I_T correspond to the reflective intensities obtained from the soil-monitoring detector and the temperature-monitoring detector, and I_s/I_T is the calibrated intensity. As can be seen, this monitoring system eliminates the temperature influence.

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References

1. K. Hirai, T. Suda, K. Tanaka, K. Sako and R. Fukagawa: Study on method for monitoring soil moist state and groundwater level using ultrasonic waves to predict slope failures [in Japanese], THE 25th SENSOR SYMPOSIUM on Sensors, Micromachines, and Applied Systems, LN-7, 2008.
2. T. Suda, K. Hirai, K. Tanaka, K. Sako and R. Fukagawa: Study on monitoring of soil moisture and ground-water level using ultrasonic waves for prediction of slope failures [in Japanese], IEICE technical report 108(410), pp.117-122, 2009.