2P2-3

Compared to soil physical properties of Japanese subsoils by using ultrasonic microscope

Chaity Saha[1‡], Yuki Kawaguchi[2], Yuji Maejima[3], Kaori Momohara[3], Munehiro Ebato[3], and Marie Tabaru[1*] ([1]Tokyo Tech; [2]HONDA Electronics; [3]NARO)

1. Introduction

Soil has been analyzed using light and electromagnetic waves, offering wide-area measurement but low real-time performance, leading to a focus on ultrasonic waves for better real-time capabilities[1)]. Research includes Umezu et al. on resistance and velocity, highlighting soil's ultrasonic attenuation of 50-100 dB/cm[2)]; studies on soil with 70% moisture in Niigata, Tokyo, and Tottori; velocity measurements at 500 kHz; Koyama on clayey soil in Osaka[3)]; Ishimoto et al. in Hongo and Marunouchi up to 700 Hz[4)]; Hiraoka et al. on soil water content in Toyoura sand[5)]; and analysis in Ibaraki on various soils using the transmission method[6)].

Ultrasonic microscopy, primarily used for biological research like studying cells, have never been researched for soil property measurement. Ultrasonic microscopic images of soil blocks are successfully acquired for the first time in the world by our research group[7)]. In this study, the possibility of distinguishing different types of soil is discussed.

2. Measurement of acoustic impedance

An ultrasonic microscope uses high frequency ultrasonic waves of several tens of MHz to get images of acoustic parameters like sound velocity and impedance with about 10 μm resolution[8,9)]. The system obtains ultrasonic echoes from the measurement sample through water and calculates the reflection intensity, S_{ref} by Eqs. (1) and (2) based on the acoustic impedance differences between water and the sample.

$$S_{ref} = \frac{Z_{sub}-Z_{ref}}{Z_{sub}+Z_{ref}} \times S_0 \quad (1)$$

$$S_{target} = \frac{Z_{target}-Z_{sub}}{Z_{target}+Z_{sub}} \times S_0 \quad (2)$$

The reflection intensity S_{ref} is measured using Z_{sub} as the acoustic impedance of water and Z_{ref} as the acoustic impedance of polystyrene, to obtain a correction factor S_0 (Eq. (1)); the intrinsic acoustic impedance Z_{target} of a soil sample is then derived from Eq. (2) and S_0.

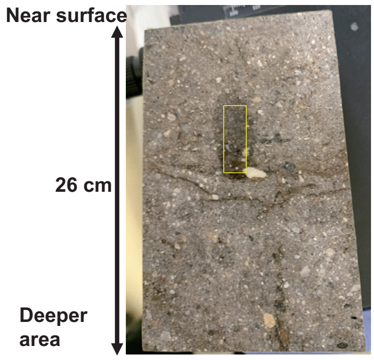
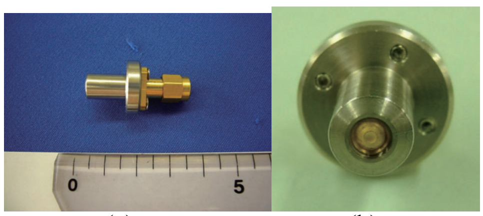


Fig. 1 Picture of soil block sample produced from Stagnogley soils (Furano, Hokkaido).

3.Experiment

In the study, soil blocks were made from subsoils of Stagnogley soils (Furano, Hokkaido) and Allophanic Andosols (Hokota, Ibaraki) by solidifying them with unsaturated polyester resin, as soil tends to changes in shape, and these blocks were used as measurement samples[10)]. Fig. 1 shows the soil block of Furano.

A pulse signal from an ultrasonic transmitter/receiver with a 20-750 MHz bandwidth was deployed to drive an 80 MHz ultrasonic probe with a 2.4 mm diameter and 3.2 mm focal length that was made of P(VDF-TrFE) piezoelectric thin film (Honda Electronics) (Fig. 2). It was used to emit focused waves to a soil block, receiving echo signals. The area scanned was 4.8 × 4.8 mm² at 0.016 mm intervals, with water interposed between the probe and a soil block. The ultrasonic microscope images of the soil blocks were created by combining each acquired images in the measurements.



(a) (b)

Fig. 2 Pictures of P(VDF-TrFE) thin-film ultrasonic probe. (a) Entire probe and (b) transmitting/receiving section.

E-mail:[‡]saha.c.aa@m.titech.ac.jp,
[*]tabaru.m.ab@m.titech.ac.jp

4. Results and Discussion

Fig. 3 presents the acoustic impedance image of the block of Stagnogley soils (Furano), scanned in the yellow squared area of Fig. 1, with impedance values ranging between 1.5 and 3.4 kg/m^2s. In both Fig. 1 and Fig. 3, the upper part of the image represents a location closer to the ground surface, while the lower part indicates deeper strata. The acoustic impedance of Stagnogley soils tended to increase with increasing depth.

Figs. 4 (a) and (b) show optical microscope image (Sanwa Supply, 400-CAM058) and acoustic impedance image of the block of Allophanic Andosols (Hokota), respectively. The image from Hokota has the finer granules as compared to that from Furano.

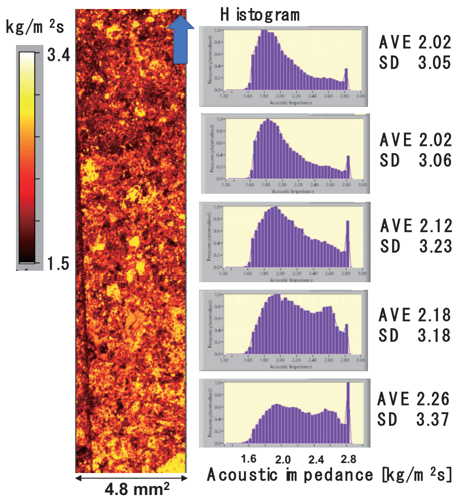


Fig. 3 Acoustic impedance image and histogram of soil block sample produced from Stagnogley soils (Furano, Hokkaido).

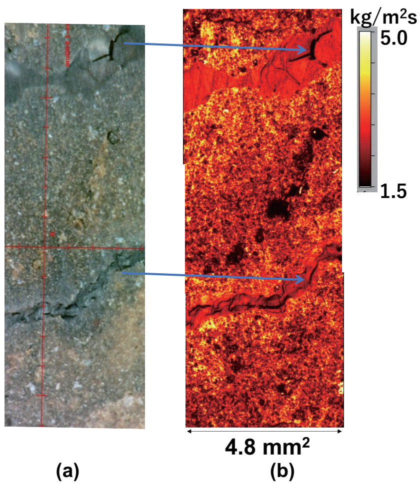


Fig. 4 Block sample of Allophanic Andosol (Hokota, Ibaraki): (a) optical microscope image, (b) acoustic impedance image.

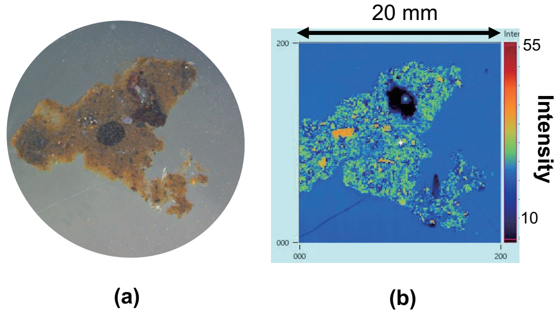


Fig. 5 Crumb structure: (a) optical microscope image, (b) reflection intensity image.

Fig. 5 (a) show the optical microscope image of the crumb structure. Fig. 5 (b) shows the ultrasonic reflection intensity distribution, with the findings indicating that correlated images could be obtained from these.

5. Summary

In this study, ultrasonic microscopic images were acquired as a novel method for soil physical properties, marking a global first. Differences in acoustic impedance distribution between two soil types reflected variances in soil physical properties. Future work will optimize parameters, analyze images, discuss soil composition's relationship with acoustic impedance.

References

1) *Illustrating Physical Investigation* (Society for Physical Investigation, 1992). [in Japanese]
2) Y. Umezu and K. Imo, Ultrasonic Techno **16**, 48 (2004) [in Japanese].
3) S. Koyama, Soil Physics Society of Japan **42**, 48 (1980) [in Japanese].
4) M. Ishimoto and K. Iida, Bulletin of the Earthquake Research Institute **15**, 67 (1937).
5) N. Hiraoka, T. Nakano, K. Tanaka, M. Fujimoto, R. Fukagawa, A. Tokari and N. Iwasa, Disaster Prevention Papers on Historic Cities **8**, 131, (2014) [in Japanese].
6) H. Nagao, M. Ebato and M. Tabaru, Proc. IEICE General Conference, 2023, p.20. [in Japanese]
7) M. Tabaru, C. Saha, Y. Kawaguchi and M. Ebato, Research Committee of Acoustic Imaging, 2023, 4 [in Japanese].
8) K. Kobayashi, S. Yoshida, Y. Saijo, and N. Hozumi, Ultrasonics **54**, 7, 1922 (2014).
9) Y. Ogura, Y. Hara, M. Ninomiya, T. Yamashita, C. Katagiri, K. Kobayashi, Y.Shiihara and N. Hozumi, IFSCC congress, 2020, 10 pages.
10) M. Arifin and R. Devnita, Jurnal Geologi Indonesia **3**, 195 (2008).