Development of a transmission test apparatus of elastic waves through a sand soil under dry, saturated and partially saturated conditions

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It is still vailed how elastic waves propagate in partially water-saturated unconsolidated media. Barrière et al. (2012, GJI) detected changes in amplitude and propagation velocity of transmitted waves through a 1-m long sand soil during water injection and drainage. However, the transmitted waves may not be stable, because they are generated by hitting a steel ball to granite plate. Also, the frequency band they analyzed was limited within 1.6-1.8 kHz. It is necessary to improve the experimental setup to estimate the spatial variations of the medium changes or to utilize the later phases of the transmitted waves, for example, reflection phases which are generated at the boundaries between the solid-fluid or fluid-fluid phases. In this study, we realized a system where we adopted a reproducible source (hereinafter, referred to as a shaker) and used a signal with a higher and broader frequency band of about an octave range in several ten kilohertz so that the wavelengths were longer than path lengths. In order to demonstrate the utility of our developed system, we here evaluated the stability of transmitted waves through a sand soil under dry or saturated conditions.

We made a sand soil with the thickness of about 100 mm in a container (375 L×255 W×235 H mm^3), which consisted of a permeable part (Wet part) and two impermeable parts (Impervious part and Dry part). We installed the shaker into Dry part to prevent change in the coupling between the shaker and the sand. 5 accelerometers were installed in the sand soil: one (AC_{ref}) was in the vicinity of the shaker as a reference, and the others (AC_{1-4}) were aligned horizontally in Wet part. We designed a linear sweep signal from 1 kHz to 50 kHz as a transmitting signal. The transmitted waves were recorded at the sampling rate of 204.8 kHz, and we obtained hourly stacked waveforms. 4 Soil moisture meters were also installed to monitor water contents in the sand soil.

We successfully recorded the transmitted waves at all of the accelerometers with high signal to noise ratio for the frequencies of the sweep signal. The fluctuations of spectral amplitude and phase for AC_{ref} were within ±0.5%, ±0.04 rad under both dry and saturated conditions, respectively. This shows that we succeeded in stably radiating the elastic waves from the source. Similarly, the fluctuations of spectral amplitude and phase for AC1-4 were within ±20%, ±0.2 rad under both dry and saturated conditions, respectively. According to the results of Barrière et al. (2012), the expected changes in amplitude and velocity may become about 5% and 15% during saturation or drying, respectively. Their observed velocity became lower than about 160 m/s, therefore, velocity change corresponding to our phase change become at most ~2% for analyzed frequencies. Therefore, these results suggested that our system enables us to sufficiently detect changes in amplitude and propagation velocity of transmitted waves through an unconsolidated porous medium while the degree of fluid saturation or water level changes.

Keywords: Wave propagation, Sand soil, Saturation