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密に充填した不飽和多孔質体中の間隙スケールの水分移動

Pore-scale water movement in dense-packed and unsaturated porous media

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1. Introduction

The 24 space agencies, including JAXA, are planning crewed space missions on the surface and surroundings of the moon by 2028[1)]. During long-term space missions, plant growth under extra-terrestrial conditions can expect to provide food and psychological benefit to astronauts[2)]. Low water content is one of the environmental stresses for the plant; however, several researchers reported water infiltrates slower into the porous media under microgravity than Earth gravity. Three hypotheses, which are "air entrapment[3)]," "particle separation[3)]," and "interruption on widening void space[4,5)]," could explain this slower water infiltration under microgravity. "Particle separation" can be reduced by dense packing. Therefore, our objectives in this study were (1) to evaluate water flux density in dense-packed and unsaturated porous media, and (2) to reveal what makes water infiltration slower under microgravity than 1 G.

2. Materials and Methods

Two layers of the glass beads (BZ-08, AS ONE; BZ-1, AS ONE) were filled in the Hele-Shaw cell to observe

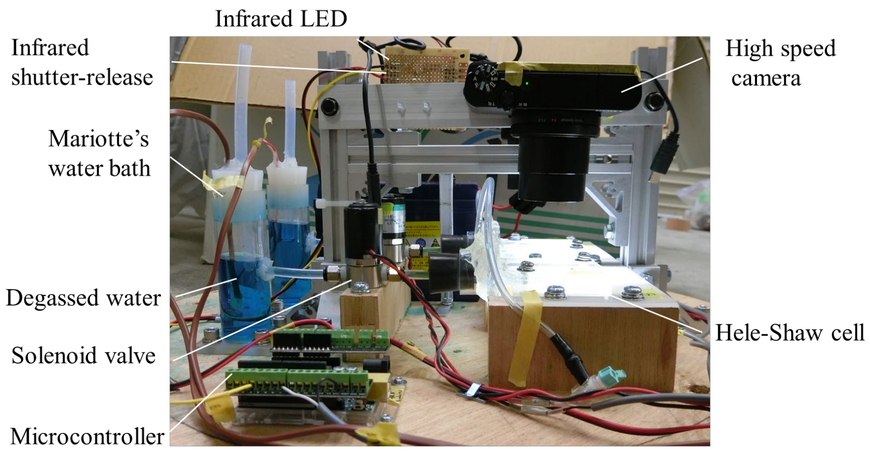

Figure 1. Experiment apparatus

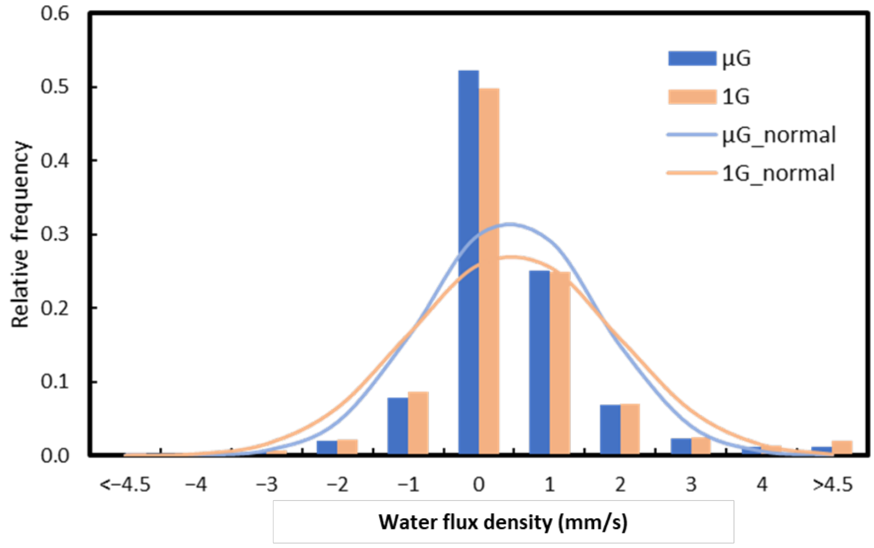

Figure 2. Relative frequency distributions of water flux density under microgravity and Earth gravity.

water infiltration by a high-speed camera (DSC-RX100M5A, SONY) at 960 fps. The Hele-Shaw cell was connected to the Mariotte water bath to let dyed, and distilled water infiltrate into the glass beads. The infiltration was controlled by a solenoid valve attached between the glass beads and the water bath. The solenoid valve was opened 0.2 s later than the beginning of the microgravity condition by a microcontroller board (Arduino Uno, Arduino) and an acceleration sensor (MMA7361, Freescale Semiconductor). The infiltration was observed under 2.4 s microgravity condition induced by the free fall from COSMOTORRE (HASTIC) and under Earth gravity. Water flux density and wet part on each bead were calculated from the

3. Results and Discussion

Figure 2 shows relative frequency distributions of water flux density under microgravity and Earth gravity. Water flux density was not significantly different in dense-packed porous media under microgravity and Earth gravity (p=0.30). "Air entrapment" did not observe under microgravity and Earth gravity. The pore space in porous media was too small to trap the air. Relative frequency distributions of the wet part of the beads under

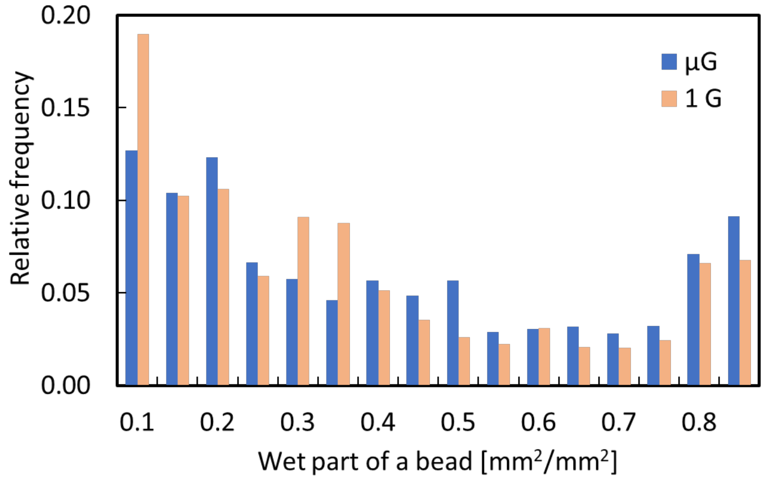

Figure 3. Relative frequency distributions of wet part of the beads.

microgravity and Earth Gravity were shown in Figure 3. When the wet part ratio was 0.1 to 0.3 and 0.8 to 0.9, the wetting front was on the widening of the pore. The wet part ratio of 0.5 to 0.8 indicates the wetting front was on the narrowing of the pore. The higher frequency at the wet part ratio of 0.1 to 0.4 and 0.8 and 0.9 was observed both under microgravity and Earth gravity. However, there was no significant difference between the wet part ratio under microgravity and Earth gravity. Therefore, "interruption on widening void space" was not gravity dependent.

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This presentation is part of the reviewed paper* published in Water Journal.

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