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部分凍結した未固結砂における超音波減衰測定
Attenuation measurements of ultrasonic wave in partially frozen unconsolidated sands

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Ultrasonic wave transmission measurements were conducted in order to examine the influence of ice-brine coexisting system grown in unconsolidated porous material on ultrasonic P- and S-waves. We observed the variations of a transmitted wave, changing its temperature from 25 degree C to -15 degree C and quantitatively estimated attenuation for unconsolidated porous material during the freezing of brine in porous material by considering different distances between the source and receiver transducers. This paper is concerned with attenuation at ultrasonic frequencies of 350-600 kHz for P-waves and 150-250 kHz for S-waves. The waveform analyses for P-waves indicate that the attenuation curves reach their peak at a temperature of freezing point and gradually decrease with decreasing temperature, which is interpreted as the increase of the ice fraction or the increase of the effective bulk modulus of the system. The waveform analyses for S-waves indicate that the attenuation decreases with decreasing temperature, which is interpreted as the increase of the effective shear modulus of the system due to the increase of cementation of ice in the frozen sand. The laboratory experiments of the present study demonstrated that ultrasonic waves with such a frequency range are significantly affected by the existence of a solid-liquid coexistence system in the porous material. From liquid phase to around the freezing point, the presence of a partially frozen brine increases both velocity and attenuation. Attenuation estimation for P-wave is repeatable and stable while that for S-wave is not. However, the frequency content of S-wave shifts to higher with decreasing temperature. This implies that the attenuation decreases with decreasing temperature. In terms of a plausible mechanism for attenuation, we must consider the physical interactions between pore fluid, sands, and ice, that is, the pore microstructure and permeability in such system is important. Furthermore, several considerations on velocities using some theoretical models are also demonstrated.