Measurement of soil air content using acoustic standing waves

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1. Introduction Gas exchange between the atmosphere and the air in the soil is a important process because it is related to the supply of the oxygen to the organisms in soil and emission of greenhouse gases from soil to the atmosphere. Soil air consists of the air connected to the atmosphere and the air isolated from the atmosphere. The continuous air acts as a flow path through which the soil exchange the air with atmosphere. It is important to estimate the amount of the continuous air in soil and to reveal the relationship between the continuous air content and other physical properties such as air permeability. However, there are no major experimental method to measure the continuous soil air content. Therefore we introduced the method based on the principle of acoustic waves.

2. Materials and methods The experimental apparatus is shown in Figure 1. It consists of cylindrical sampler of 5cm inside diameter and vinyl pipe of 2.5cm inside diameter and 25,50,100cm length. The pipe is equipped with speaker and microphone on its side. The speaker can make the sound wave whose frequency increases gradually from 0 to 1000 Hz. We examined the minimum frequency at which the sound pressure reached the local maximal value. The standing wave occurs whose wave length was four times the length of the pipe. We call the frequency of standing waves resonance frequency. The soil packed in samplers was from the paddy field in Nantan City, Kyoto Prefecture and 4.5mm mesh control was done for this soil. We used samplers of 50 and 100cm^3 in volume. The bulk densities were 0.88 and 1.17 Mg m^{-3}. We used four samples in experiment. The amount of air in the samples were 14, 23, 29, 45 cm^3.

3. Results The relationships between the soil air content and the resonance frequency was shown in Figure 2. Horizontal axis is the soil air content times resonance frequency divided by the cross section of the pipe and the acoustic velocity. The longitudinal axis shows the resonance frequency times the length of the pipes and divided by the acoustic velocity. The relation was linear for almost samples except for the densely packed sample in 100cm^3 sampler. The resonance frequency decreases with increase of the amount of soil air. Twenty five cm long pipe shows the largest amount of change of resonance frequency. The densely packed sample in 100cm^3 sampler shows smaller change in resonance frequency compared with the other samples.

4. Discussion The result shows two patterns of relationships between soil air content and resonance frequency. We first consider the large change in resonance frequency with increase of air content. The air in the loosely packed samples can oscillate with easily compared with that in the densely packed samples. The increase of air content of soil make the air of soil surface oscillates more easily. As a result, the frequency of standing wave decreases. This condition can be modeled simply using the one spring whose strength is determined by the volume of air confined in sampler. The other pattern in Figure 2 shows that we must consider the effect of the large resistance to oscillations when soil is densely packed. Densely packed samples show the different frequency. This fact indicates that the surface impedance is affected strongly by the slight change of condition of soil surface or by simply doubling the volume of sampler. We need to clarify the extent of soil air which can affect the impedance of soil surface.

5. Conclusion The relationships between the soil air content and frequency of standing waves were examined to measure the soil air content connected to the atmosphere. The loosely packed soil sample shows lower resonance frequency than the densely packed soil sample. Non dimensional parameters about frequency and volume of soil air show general linear relationship regardless of the length of pipes.

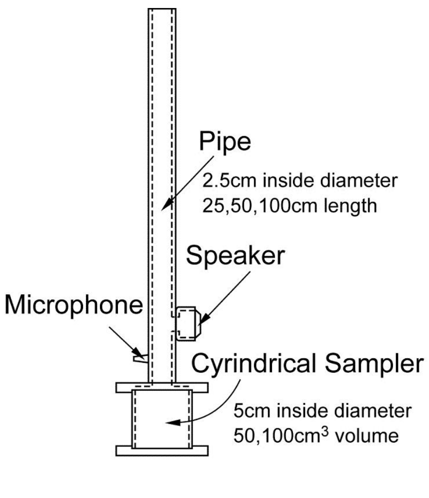

Figure 1 Experimental apparatus

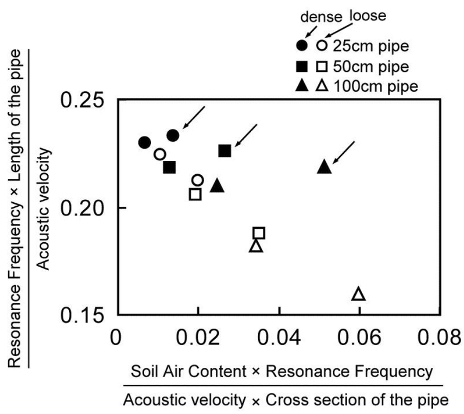

Figure 2 Relationship between resonance frequency and soil air content