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Revisiting the block method for evaluating thermal conductivities of clay and granite ☆

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ABSTRACT

Determination of thermal conductivities of porous media using the contact method was revisited and revalidated. Thermal conductivities of granite and clay were determined in the laboratory with and without the use of thermal interface material (TIM) (Arctic Silver®) to reduce contact resistance. KD2 probe was also used with and without TIM to compare results. Thermal conductivity of dry clay sample increased from 0.68 W/mK to 0.85 W/mK while that of granite sample increased from 2.95 W/mK to 3.95 W/mK with TIM. The difference in thermal conductivities with and without TIM was significant at (P>0.05).

1. Introduction

The concept of heat transfer in porous media has increasingly found relevance in sciences and engineering. Thermal properties of porous media are of great importance to environmental sciences, agriculture and engineering, especially in relation to temperature and heat flux in the root and rock zones. It is also important in studying energy, water balance and mass exchange processes occurring across porous media surfaces. Contact resistance error has been the greatest concern with regards to accuracy of thermal properties measurements [1–4]. The connection between thermal properties and moisture content of soils and rocks obtained during laboratory experiments has also been used to determine these properties in the field [5,6]. Thermal parameters depend mainly on the soil or rock constituents, soil texture, porosity and moisture content. Heat capacity is a material property which expresses the fact that for changing the temperature of a certain volume of material, energy flows in or out and usually linked to the density of the material. When dynamic processes are involved, change of temperature vs. time, at known boundary conditions is defined by both thermal conductivity and heat capacity. Block method [7–9], which employed a fabricated block of an appropriate material at a uniform temperature and placed on the sample surface had been used in the past to determine thermal properties of porous soil materials. The technique had largely been abandoned due to accuracy concerns regarding thermal contact resistance between the block and the sample surface. Investigators have also made attempts to measure thermal properties of rock materials using various methods [10], but very little is known on the use of block method to determine thermal properties of rocks. The objectives of this work were therefore to revisit the block technique on soil samples using thermal interface material to address its limitations, and attempt to extend its use to rock samples.

2. Method and instrumentation

Block device was used to make measurements of thermal conductivity of soils and granite, while KD2 thermal analyzer was used to make instantaneous measurements for validation.

2.1. Block device set-up

Block method device was fabricated from Perspex (10×10×4 cm) with $\lambda_p = 0.18568$ W/mK, $C_p = 1.728 \times 10^{-4}$ J/m^{3}K. Copper – constantan thermocouples line the flat surface and at several depths (2, 4, 8, 16 and 32 mm) inside the block (Fig. 1), at which the initial temperature at the instant t = 0, which must be uniform, is measured. The device obtains measurements of thermal properties at the surface which no other method that use line source probes does including KD2 thermal properties analyzer [11,12]. Since the materials of interest were uniform with depth, the block and the KD2 data should agree, however many times in soil, the surface is either much wetter or drier than below so that the block method is really the only way to get the true surface layer thermal properties. The block with an insulation cover (2.54 cm – thick Styrofoam) is placed in a thermostat and after a few hours, the temperature at the surface of the block and within it was recorded for a short time to measure the initial temperature of the block and ensure a uniform temperature. After removing the insulation plate covering the lower surface, the block is

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