PRELIMINARY TESTS OF THERMAL CONDUCTIVITY OF SELECTED SOIL TYPES

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Abstract:

The paper discusses the topic of thermal conductivity investigation of soil. This problem is especially crucial for the design and exploitation of ground heat exchangers. Such systems located in the soil can either extract heat from the ground or transport it there for season storage. Nowadays, these and similar installations are used in connection with renewable energy systems – for example heat pumps. The paper presents the preliminary test results and characteristic properties of selected kinds of soil. Further tests could help to determine the usefulness of different soil types for heat exchanger applications.

Key Words: Conductivity, soil, thermal properties

Introduction

Thermal conductivity is a property of engineering materials and its value is often determined in order to assess the insulation characteristics of building materials. However, in view of the current trend to efficiently use energy, soil thermal properties become interesting and scientific effort is made in this field. The precise knowledge of the thermal conductivity of soil can help to properly design ground heat exchangers. The energy from the ground might be used, among other applications, to heat homes in winter or provide domestic hot water throughout the whole year.

Abu-Hamdeh and Reeder (2000) focused their research on the influences of bulk density, moisture and salt as well as organic matter of soil samples - repacked and sieved. They wrote that conductivity rose with soil density and moisture concentration. Abu-Hamdeh (2003) in a later paper also analysed the influence of the concentration of water and bulk density of soils. Tang et al. (2008) investigated compacted bentonite and the influence of dry density, water content, saturation on conductivity. Abuel-Naga et al. (2009) presented experimental tests showing that the values of thermal conductivity were higher with the rise in soil density. O'Donnell et al. (2009) considered a relation between thermal conductivity and moisture of soil. In terms of theoretical studies, Singh et al. (2011) presented a possibility of using a method of artificial neural networks for the prediction of effective thermal conductivity of moist porous systems.

Samples and measurements

Sample preparation and preliminary tests of basic properties is quite significant from the scientific point of view. The paper by Grobelska and Ludynia (2010) discusses a sample preparation method.

In the present research two kinds of soil (sasiCl and Cl) have been selected for the experiments and Table 1 shows their basic properties determined directly through measurements or calculated basing on the results of the laboratory tests.

Table 1. Basic properties of the investigated soil types.

Property	sasiCl	Cl	Testing method
bulk density of soil [ϱ], g/cm^3	2,32	2,05	ring method
density of solid particles [ϱ_s], g/cm^3	2,69	2,72	pycnometer method
dry density of solid particles [ϱ_d], g/cm^3	2,13	1,65	calculated
porosity [n], -	0,21	0,39	calculated
void ratio [e], -	0,26	0,65	calculated
fine fraction (f_{si+cl}), %	51,35	91,5	laser method
water content w, %	9,04	24	dry method

Additionally, the SEM images have been made in order to have an insight into the surface structure of the analysed kinds of soil. The results of the scanning microscopy tests have been presented below in Figures 1a and 1b for the magnification of 2500 times.

a) b)

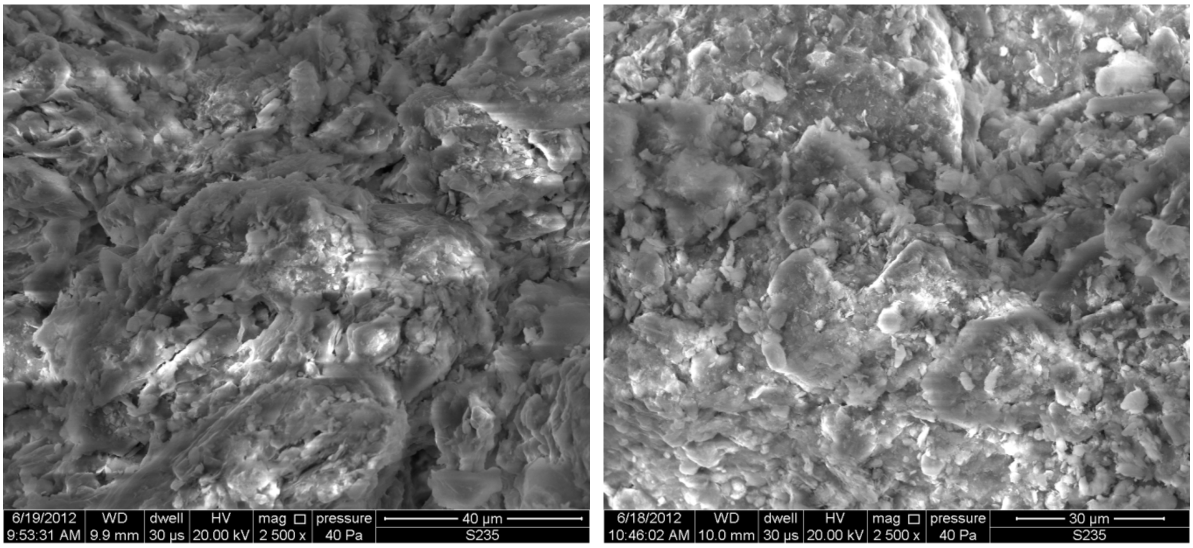

Fig. 1. SEM images of sasiCl (a) and Cl (b).

The measurements of thermal conductivity have been conducted on samples of ca. 12x12cm in the a plate apparatus. This equipment comprises two parallel plates located in an insolated chamber to reduce heat losses. One plate acts as a heater (kept at the temperature of ca. 20^{o}C) and the other a cooler (temperature ca. 0^{o}C). The temperatures could be changed. The conductivity is determined by the equipment based on the measured temperature difference, thickness of the analysed sample as well as heat flux transferred through the sample and measured during the test. The correct steady – state measurement is carried out if the temperatures of the plates reach the given values. The heat flux should also be constant. Figures 2a and 2b show example graphs of changes in temperatures of the plates while Figure 3 – an example heat flux curve.

a) b)

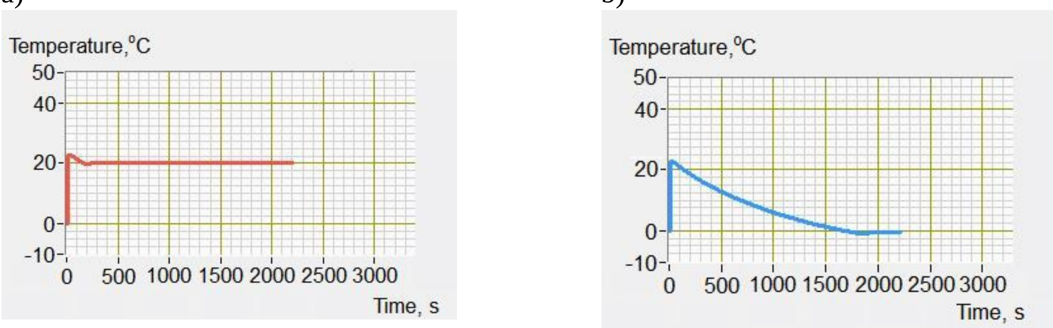

Fig. 2. Example temperature changes of the heater (a) and the cooler (b).

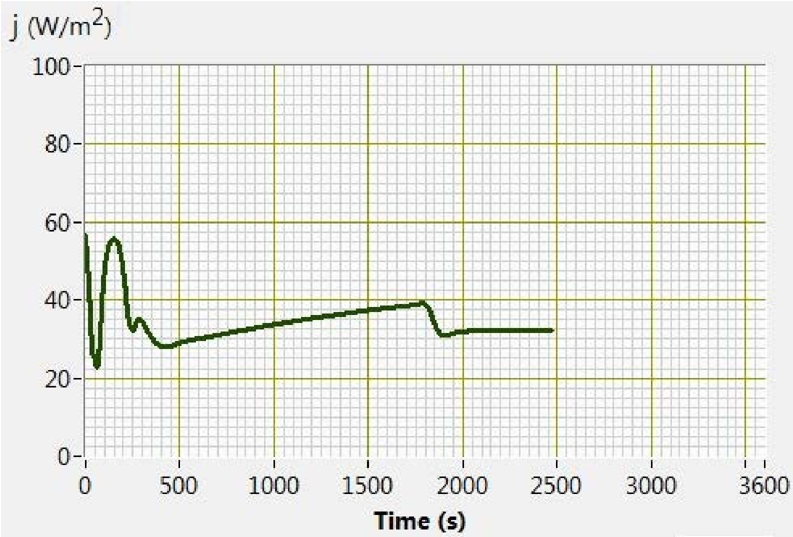

Fig. 3. Example changes of the heat flux.

Test results

The presented research enabled to determine thermal conductivity of the analysed soil samples. The results have been presented in Table 2 and Figure 4.

Table 2. Thermal conductivity of the tested soil samples.

Sample:	**sasiCl**	**Cl**
Thermal conductivity, W/(mK)	0,483	0,351

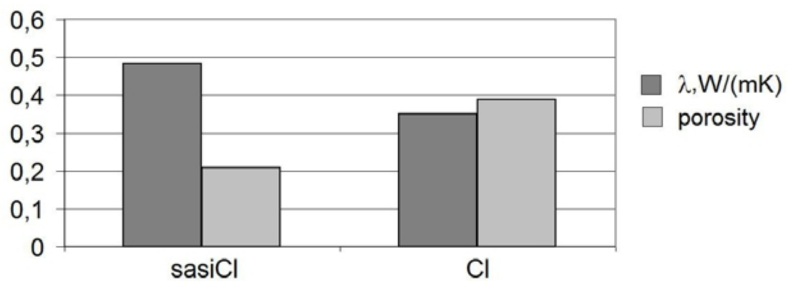

Fig. 4. Thermal conductivity and porosity results.

The above test results are in general agreement with literature data on thermal conductivity of soil which indicates that the experimental method is applied correctly. The higher value was recorded for sample which has lower porosity while the sample of higher porosity had lower conductivity. This can be explained by the presence of voids that increase the insulating properties of the materials. Basing on the good understanding of the soil thermal conductivity, ground heat exchangers might be designed more accurately in given conditions.

Conclusion

Current trend in energy recovery is common in almost every country. Ground heat exchangers can be used such practical applications as heat pumps systems. Consequently, a detailed knowledge about the soil thermal parameters is crucial in a proper design of the whole installation. Nevertheless, more thorough analysis and calculations are necessary in this field. More experiments could also provide a basis for creating a model of thermal conductivity of different types of soil.

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