Investigation of Thermal Conductivity of Materials

Students: Ryan Hernandez, Daniel Ben-Hur, and Christian Gonzalez
Facility Advisor: Dr Krishna Prasai

Abstract:

The thermal conductivity of a given material refers to the ability of the material to conduct heat. We measured the thermal conductivity of numerous materials, utilizing two different devices, namely; The TLS-100 and the Leti-40. The soil humidity test involved the TLS-100, and the Leti-40 was used to measure the thermal conductivity of three different solid samples. The thermal sensing probe of the TLS-100 was used for the direct measurement thermal conductivity of different soil samples. On the other hand, the heating plate, cooling plate and proportional integral and differential (PID) control system of the LETI - 40 were utilized for the indirect measurement of the thermal conductivity of different solid materials. The data obtained from the TLS-100 measurements was used to analyze the change in thermal conductivity of soil samples with change in humidity and the data obtained from the LETI - 40 was used for the determination of thermal conductivity of different poor conducting solid materials as well as to analyze the consistency and precision of the machine. Analysis of our soil samples data clearly indicated that the thermal conductivity of a soil sample has a direct correlation with the water content of the soil samples. Based on our measurements it is clear that the LETI-40 produces precise and consistent data for the measurement of thermal conductivity of solid samples.

Soil Based Experiment Using TLS-100

In order to investigate the effect of moisture on the thermal conductivity of different soil samples, a TLS-100 probe was used for the direct measurement of thermal conductivity with different levels of hydration. We first measured the mass and thermal conductivity of a dry soil sample. We then keep on adding a known mass of water and the corresponding thermal conductivity of the sample was determined for each hydration level. Every single measurement was repeated multiple times to determine the experimental uncertainty of the measured result. The entire process was repeated for the second soil sample.

Data and Analysis for Soil Samples

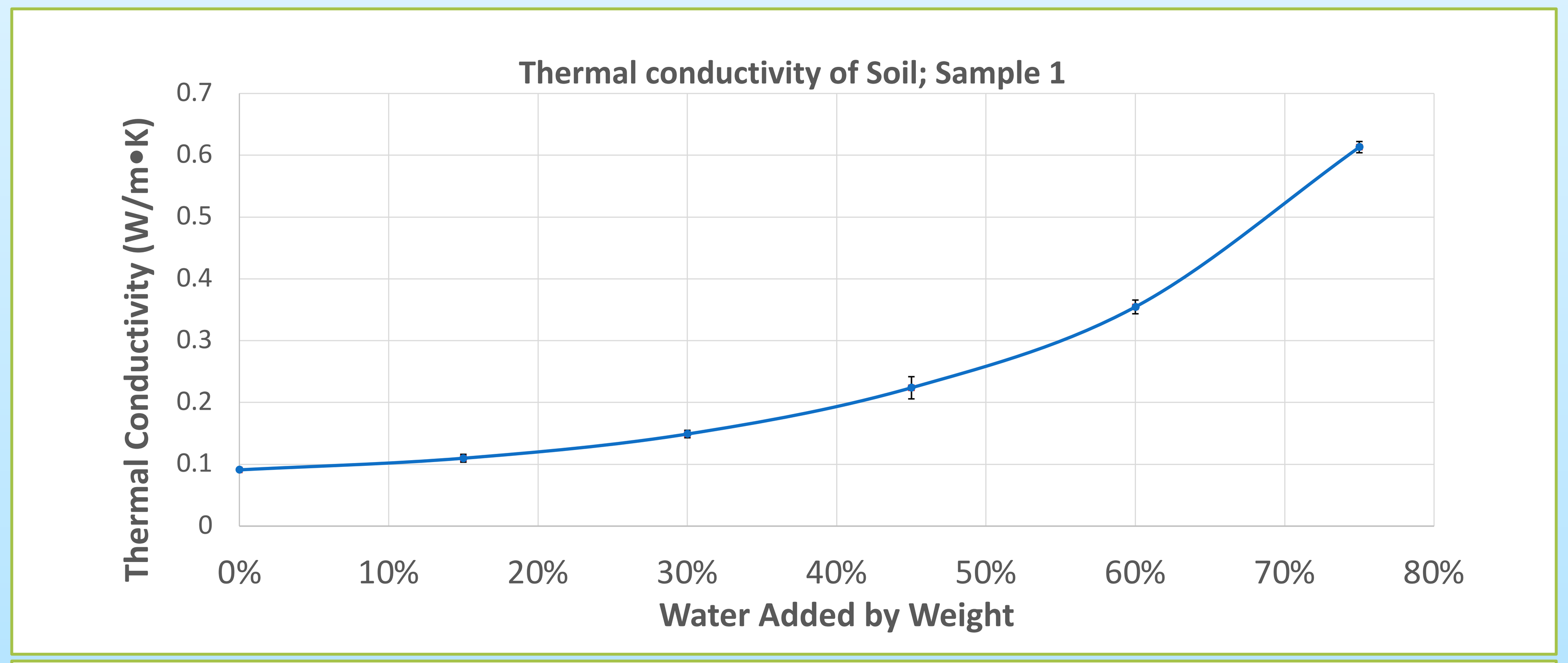

Figure 1

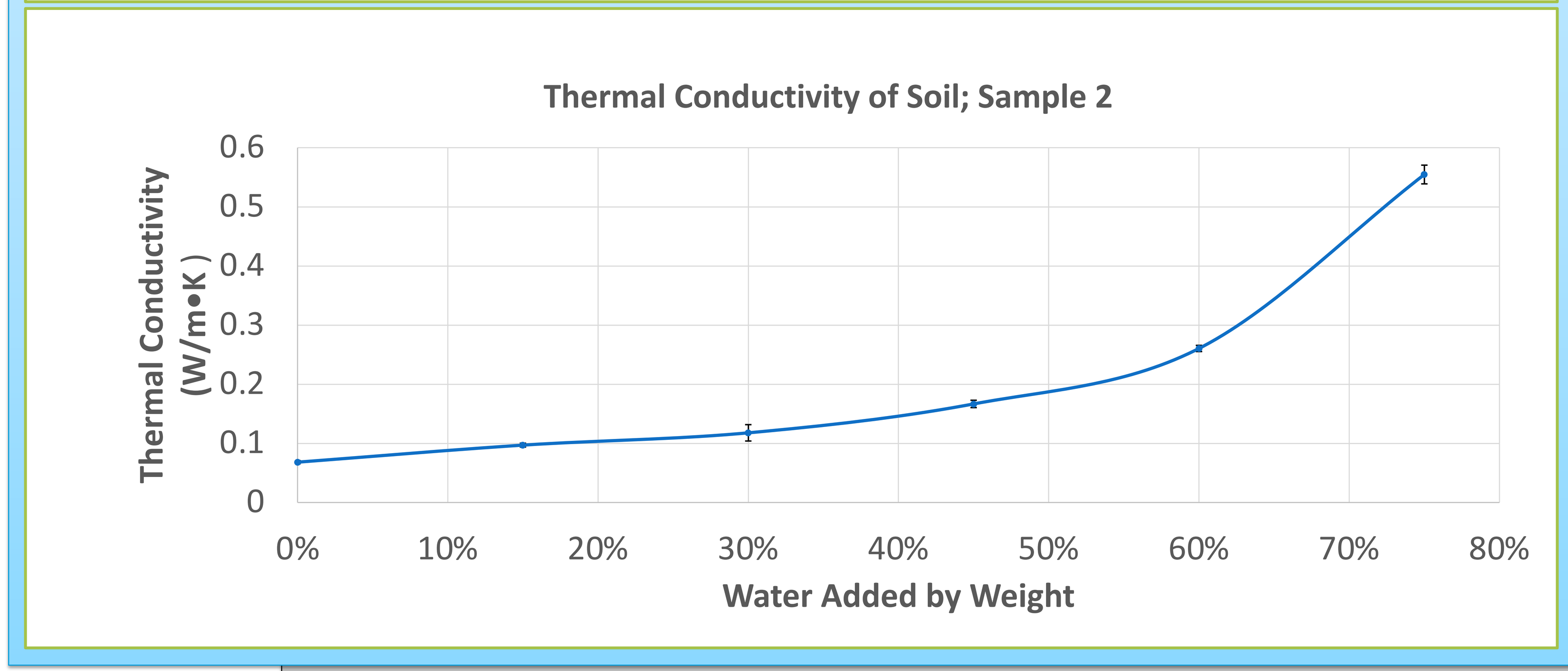

Figure 2

Figure 1 and figure 2 demonstrate the typical responses when the water content is incrementally increased in two different soil samples. Water was added and mixed based on the previously calculated water-soil mass ratio. The error bar represents the experimental uncertainty on each measurement. Data collected for both soils samples indicate a roughly linear trend as the water content is increased.

Conclusion

In both of the soil samples there is a strong correlation between the thermal conductivity and the humidity of the soil. Increasing the humidity also incremented the soil's thermal conductivity. Thermal Conductivity analysis may establish much greater insight into soils that can be used for our agricultural as well as industrial worlds. However, these results are not conclusive because of the limitation of the apparatus used and the time duration of the research.

Leti-40 Experiment

Solid Based Experiments Using LETI - 40

The LETI - 40 is a comprehensive apparatus of heat experiment and it uses a simple yet outstanding idea when testing the thermal conductivity of a material. A "hot plate" is heated to the desired temperature, while keeping a "cold plate" at room temperature underneath, we can "sandwich" a certain material, and record the change in temperature of the hot and cold plate. For each trial, a carefully prepared sample of a poor conducting solid was placed in between the heating and the cooling plate. Once the sample reached the steady-state condition the stabilized temperature of the sample disk was recorded. The cooling temperature for the cold plate was recorded and a tangent line was graphed on the cooling curve at the previously recorded stabilized temperature of the cold plate. The slope of the tangent line was used to determine rate of change of temperature. We started with white plastic, then moved onto wood, and ended with analyzing the rubber piece. For each sample, we repeated the experiment at least six times and obtained experimental uncertainty.

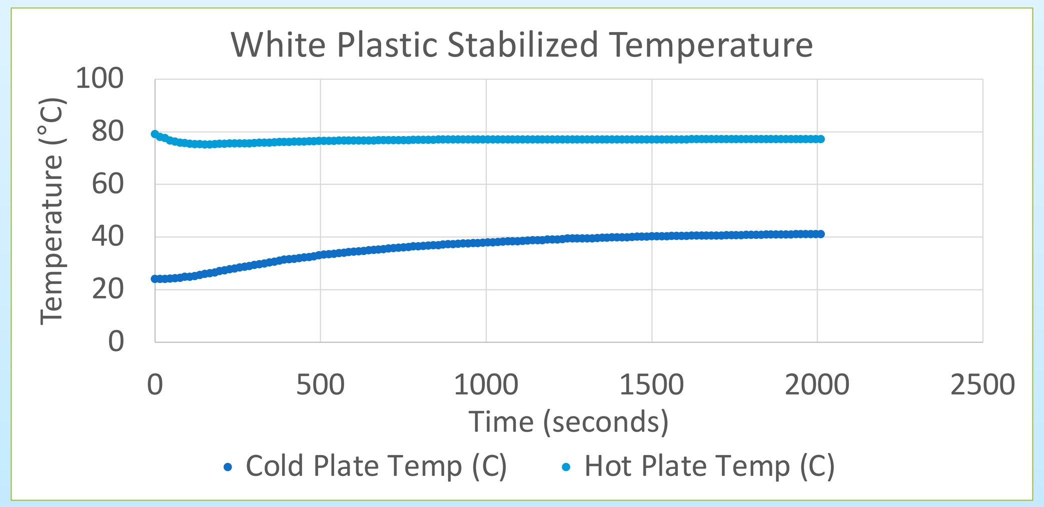

Figure 3

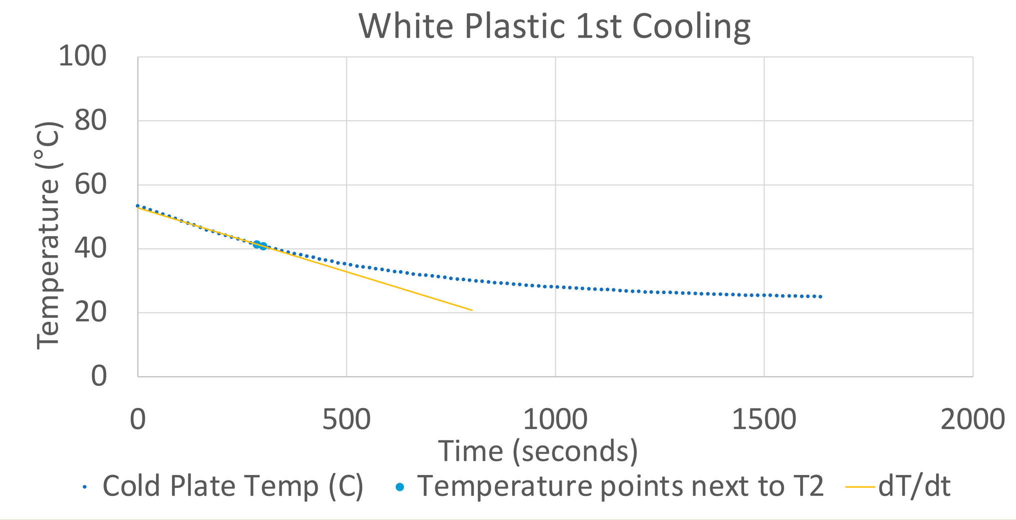

Figure 4

Figure 3 demonstrates the stabilized temperature of the "Hot" and "Cold" Plate, T_1 and T_2 stabilize as the heat being transferred is lessened for the white plastic.
Figure 4 shows the "cold" plate cooling after the material is removed and is used to find $\frac{dT}{dt}$ at T_2 for the white plastic.

$$\lambda = -Cmh \cdot \frac{\frac{D}{4} + h}{\frac{D-T2}{2} + h \cdot (T_1 - T_2)} \cdot \frac{4}{\pi \cdot D^2} \cdot \frac{dT}{dt}$$

Figure 5

Figure 5 represents the equation for the heat conductive coefficient, where C is specific heat capacity, m is mass, h is height, D is diameter, T_1 and T_2 are hot and cold plate temp, and $\frac{dT}{dt}$ is the rate of heat lost at T_2.

Material	λ
White Plastic	$(3.64 \pm 0.41) \times 10^{-5}$ (W / m K)
Wood	$(3.16 \pm 0.38) \times 10^{-4}$ (W / m K)
Rubber	$(1.18 \pm 0.15) \times 10^{-2}$ (W / m K)

Figure 6

Figure 6 shows the Measured Thermal Conductivity of the tested materials, λ is the thermal conductivity with corresponding experimental uncertainties.

Conclusion

The measured values of the thermal conductivities and corresponding experimental uncertainties indicated that the LETI-40 procedure produces 'precise' results. The low thermal conductivity of the materials like wood, rubber, and white plastic indicates that these are good insulating materials. The results, as compared to expected values, suggest that this experiment requires careful control of samples, improved thermal contact, and rigorous procedural directives to produce accurate results.