Thermal Properties of Soil Samples from Coastal Sand Landform in Ilaje Local Government Area of Ondo State, Nigeria

[1] Oluyamo, S. S., [2] Famutimi, O. F., [3]Adekoya, M. A. and [4]Aramide, T. M.
[1]Department of Physics, Federal University of Technology Akure, P.M.B. 704, Nigeria
Email: oluyamos@yahoo.com
[2]Department of Physics, Federal University of Technology Akure, P.M.B. 704, Nigeria
Email: meetlekanonline@yahoo.com
[3] Department of Physics, Edo University Iyamho, Edo State, Nigeria.
E-mail: mathewadekoya14@gmail.com
[4]Department of Physics, Federal University of Technology Akure, P.M.B. 704, Nigeria
Email: temitopearamide2@gmail.com

ABSTRACT

This study examines the thermal conductivity of some selected soil samples from coastal sand landform in Ilaje local government area of Ondo State, Nigeria. The soil samples were sieved into different particle sizes; 300 μm, 425 μm, 600 μm, 850 μm and 1180 μm with appropriate mesh and moulded in form of a Lee's disc. The thermal conductivity of the samples was determined using parallel plate method. The values of the thermal conductivity increase as the moisture content increases and decreases with increase in particle sizes for the soil samples. The values of the thermal conductivity obtained ranged between 0.3444 $Wm^{-1}K^{-1}$ and 1.8894 $Wm^{-1}K^{-1}$. It was noted that the conductivity of the landforms conforms to the range of conductivities of soil required for some specific crops such as maize, cowpea, pineapple, okro and root crops. The results in the research would be useful to soil/building engineers and soil scientists as well as modern mechanized farmers in determining appropriate land forms for agricultural and structural purposes.

Indexing terms/Keywords

Soil material, Thermal conductivity, Particle Sizes

Academic Discipline And Sub-Disciplines

Soil Physics/Thermal Properties

SUBJECT CLASSIFICATION

Material Science

TYPE (METHOD/APPROACH)

Experimental Data and Analysis

INTRODUCTION

The study of soil properties are of great significant in determining its application in agriculture and many engineering activities where heat transfer is involved especially in the soil .The importance of thermal properties in agriculture and other area of sciences and engineering cannot be overemphasized .Thermal conductivities enable engineers to determine the proper soil for road construction, water drilling and may also help farmers to determine the best soil suitable for planting of crops. It is an important attribute when conserving energy building products [1-3]. Material structure, size, porosity, moisture content, density, presence of defect, temperature and pressure and other factors are the most influenced when determining the thermal properties of a material [4,5]. Various researches had been carried out on thermal properties of soil samples without due consideration on the effect of particle sizes of the material samples. This research work focuses on determining the thermal properties of some soil samples and the effect of particle sizes/moisture content on them. The applications of the soil samples in agriculture and building industries will also be examined.

SAMPLE PREPARATION AND EXPERIMENTAL METHOD

Three different soil samples obtained from a Coastal Sand (CS) landform in Ilaje Local Government Area of Ondo State, South Western Nigeria were used in the study. The soil samples were collected at a depth of about 0 - 30 cm and Global Positioning System (GPS) were used to determine the location of the samples. The location and sources of soil collection are shown in Table 1. A mechanical test sieve shaker was used to sieve the soil samples into different particle sizes; 300 μm , 425 μm, 600 μm, 850 μm and 1180 μm respectively. The samples were oven-dried at a temperature of 50 ^{0}C for 40 minutes, compressed and turned into circular disc's shape using modified hydraulic press. The samples moisture content was determined using digital moisture meter and kept inside a desiccator to maintain constant moisture. The apparatus used was a modification of the standard Lees' disc method for the measurement of thermal conductivity by the absolute plane parallel plate technique. This utilizes a steam chest to provide a temperature of 100 ^oC on one side of the sample and subsequently cooling measurements in order to calculate the heat flow through the sample

[6] . However, the equipment used for this research work uses electrical heating without the need of cooling measurement [7]. The value for thermal conductivity (λ) of each sample of thickness (*d)* and radius (*r)* as given by [7,8] was determined using the relation.

$$\lambda = \frac{ed}{2\pi r^2(\theta_A - \theta_B)}\left[a_s\left(\frac{\theta_A + \theta_B}{2}\right) + 2a_A\theta_A\right] \quad 1$$

where e is given by

$$e = \frac{VI}{\left[a_A\theta_A + a_s\left(\frac{\theta_A + \theta_B}{2}\right) + a_B\theta_B + a_C\theta_C\right]} \quad 2$$

a_A, a_B, a_C and a_s are the exposed surface areas of discs A, B, C and the specimen respectively. θ_A, θ_B and θ_C are the temperatures of the discs A, B and C above ambient.

Table 1: Sources/ Areas Covered with their Positions Using Global Positioning System (GPS)

Landform	Sources	Longitude (^{0}E)	Latitude (^{0}N)
Coastal Sand CS1	Okonla Igbokoda, Ilaje L.G.A	004.64734	06.26388
Coastal Sand CS2	Araromi Seaside, Ilaje L.G.A	004.49828	06.33241
Coastal Sand CS3	Zion Igbokoda, Ilaje L.G.A	004.80822	06.35257

RESULTS AND DISCUSSION

The results of the thermal conductivities and moisture contents of the samples are presented in Table 2. The values obtained for the thermal conductivity ranged between 0.3444 $Wm^{-1}K^{-1}$ - 1.8894 $Wm^{-1}K^{-1}$. Significant variation in the thermal conductivity value of the soil was noticed as the particle sizes changed. The thermal conductivity decreases with increase in particle sizes. This could be due to increase in porosity with increase in particle sizes. This is in conformity to previous research. The thermal conductivity increases with increase in moisture content for all the soil samples. It was observed that Coastal Sand CS2 had the highest thermal conductivity values among the samples considered. This could also be due to the soil fine texture and smaller particles which enable it to retain more moisture than other soil samples. Moisture content has great impact on soil thermal conductivity; it serves as bridges between the soil particle sizes. This bridging increases the effective contact area between the particles which increases the heat flow and results in higher thermal conductivity. This assertion had also be noted in earlier researches [9, 10,11] . The values of the thermal conductivities of some common building materials are contained in Tables 3.

Comparing the results obtained in this research with thermal conductivity of some commonly used building materials, it was noted that the soil sample in this landform can be utilised for building construction. In addition, the thermal conductivities in the study conform to the range of thermal conductivities of soil required for some specific crops such as maize, cowpea, pineapple, okro and root crops. Hence, appropriate landforms for agricultural and structural purposes can be ascertained through the knowledge of the thermal conductivities of the soil materials.

CONCLUSION

It was established in the study that the thermal conductivity obtained conformed to the thermal conductivities of some commonly used building materials. The research is also of immense importance to engineers, soil scientists and farmers as it would assist in the knowledge of the the type and quality of soil as well as the type of crops that could be suitable for agricultural purposes in such different landforms.

Table 2: Thermal Conductivity K ($Wm^{-1}K^{-1}$) and Moisture Content M (%) Values of the Soil Samples for Different Particle Sizes

Particle sizes (μm)	K_{CS1}	K_{CS2}	K_{CS3}	M_{CS1} (%)	M_{CS2}(%)	M_{CS3} (%)
300	1.5931	1.8894	1.6410	33.6	36.5	34.5
425	1.4626	1.7804	1.5153	29.5	35.5	33.5
600	0.7772	1.6049	0.9456	29.0	34.5	30.0
850	0.6776	1.3258	0.7450	27.0	32.6	29.0
1180	0.3444	0.5463	0.6673	23.0	30.5	26.0

Table 3: Thermal Conductivity of Some Building Materials

Building Material	Thermal Conductivity ($Wm^{-1}K^{-1}$)
Brick, Insulating	0.15
Brickwork, Common (BuildingBrick)	0.6-1.0
Brickwork, dense	1.6
Concrete, Stone	1.7
Plaster, Sand	0.71
Sandstone	1.7

Source: [12]

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Authors' biography with Photo

S. S. Oluyamo, is an Associate Professor of Condensed Matter and Materials Physics at Federal University of Technology, Akure, Nigeria. He is a researcher in the areas of metal-semiconductor alloy/thin films fabrication and characterization for device applications and adaptation at dimensions ranging from bulk to nano levels. His recent focus is geared toward harnessing the potentials of the thermal properties of wood as replacement for device insulation materials such as in solar and thermoelectric devices. Soil thermal properties and utilization in relation to building, agriculture and industrial applications are other areas of research.

O. F. Famutimi, is a Master degree holder of condensed matter physics from Federal University of Technology, Akure, Nigeria. His area of interest includes fabrication, synthesis and characterization of materials for device utilization.

M. A. Adekoya, is a Lecturer at Edo University, Iyamho, Edo State, Nigeria. Presently, a Ph.D student in condensed matter physics, Federal University of Technology, Akure, Nigeria. His research interest includes Material Physics, Synthesis and characterization of nanostructured materials for improved device applications.

T. M. Aramide, is a Master degree holder in condensed matter physics from Federal University of Technology, Akure, Nigeria. His area of research includes fabrication, synthesis and characterization of materials for device utilization.