

MEASUREMENT OF THERMAL CONDUCTIVITY AND SPECIFIC HEAT CAPACITY OF THREE MAJOR GEOMORPHOLOGICAL UNITS IN AKWA IBOM STATE, NIGERIA.

ABSTRACT

The thermal conductivity (K) and specific heat capacity (C) of some samples collected from three major landforms in Akwa Ibom State, Nigeria; namely Beach Ridge Sand (BRS), Coastal Plane Sand (CPS), Sandstone/Shale Hill Ridges (SHR) were measured. Results show that an increase in ~~Specific Heat Capacity (C)~~ of the samples gives rise to a decrease in K. The SHC of the area under study falls within the range $1813.64 \text{ Jkg}^{-1}\text{K}^{-1}$ to $3313.24 \text{ Jkg}^{-1}\text{K}^{-1}$ while the soil thermal conductivity per unit depth K was between the range $0.272 \text{ W/m}^{-1}\text{K}^{-1}$ to $0.451 \text{ Wm}^{-1}\text{K}^{-1}$. The ~~SHC~~ of the soil samples has great effect on crop and construction works.

Key Words: Thermal conductivity, Specific heat ~~Capacity~~capacity, Soil and Coastal Plane Sand.

INTRODUCTION

The study of soil properties is very important and useful to determine the soil thermal conductivity. ~~Soil-the~~The uppermost soil layer of the earth's crust ~~which~~ provides support and nutrients for plant growth. Heat conduction is the transfer of heat from one part of the body at a higher temperature to another part of the same body at a lower temperature. The conduction process takes place at the molecular level and involves the transfer of energy from the more energetic molecules to those with lower energy level. Heat conduction in many materials can be visualized as the result of molecular collision (Douglas, 1991). The conduction of heat occurs only if there is a difference in temperature between two parts of the conducting medium (Raymond and Jerry, 1992). Heat flow through any soil depends on the thermal properties of the soil. Variation in temperature with thickness of the soil determines whether the soil can be used as heat source. The prediction of temperature at various thicknesses at any given time of the day throughout the year is an important tool in the design of a construction works. Thermal properties of soil samples involve many variables which may be complicated. Such variable include the soil texture, structure and composition parameter.

Similar studies of soil properties in recent time include: comparison of the thermal properties of brick samples for a passively cooled building design (Akpabio and Ekpe, 1998); thermal response of different rock samples for a passively cooled building design (Akpabio *et al*, 2004).

THEORY

Soil temperatures ~~are~~is determined by a number of factors, some of which include the location characteristics and thermal physical properties of the soil samples. The amount of radiant energy absorbed or reflected depends on the material coloration. The proportion of energy absorbed causes changes in temperature of the soil samples. Thermal radiation or radiant heat emitted by hot bodies ~~are~~is electromagnetic containing a wide range of wavelengths. These energy absorbed by the surface may be used in: (a) Heating of air outside the rock or soil surface (b) Increasing the surface temperature, (c) Heating the interior layer of the soil, or (d) Radiating to the atmosphere (Samuel and Godfrey, 1993). By conservation law of thermodynamics, heat budget equation can be expressed as: Heat flow through the soil = Heat adsorbed from atmosphere + Absorbed solar radiation – Re-emitted radiant energy

In one dimension, the above energy balance equation can be written as:

$$-k \left(\frac{\partial T}{\partial x} \right)_{x=0} = h(T_{\text{atm}} - T_{(x=0)}) + \alpha I - \epsilon \Delta R \dots\dots\dots 1$$

Where k = thermal conductivity of the soil sample;

T = soil temperature,

h = heat transfer coefficient at the surface;

T_{atm} = atmospheric air temperature,

α = solar radiation absorptivity,

I = intensity of solar radiation,

ε = long-wave emissivity of the surface and

ΔR = difference between the incident long wave radiation and the radiation emitted from the surface (Akpabio *et al*, 2004); but solar temperature T_s is given ~~be~~as:

65 $T_s = T_{atm} + (\alpha \frac{I}{h}) - (\epsilon \Delta \frac{R}{h}) \dots\dots\dots 2$

66 With this, (Moustafa et al, 1981) assumed a general solution of the form:

67 $T_{(x,t)} = a_0 + \sum_{m=1}^{\infty} \{am \exp[i(mwt + \alpha mx)]\} \dots\dots\dots 3$

68 But, $\alpha m = (mwpc/2k)^{1/2}(1-i)$; where C = specific heat capacity of the soil sample,
 69 ρ = density of the sample, and $\omega = 2\pi/\text{period } T$. Show the dependence of material
 70 temperature with thickness of the periodic variation of temperature at the surface.
 71 The real part of the equation (3) can be expressed as:

72 $T_{(x,t)} = a_0 + \sum \{am \exp(-\alpha mx) \cos (mwt - \alpha mx)\} \dots\dots\dots 4$

73 Equation (4) can be modified as:

74 $T_{(x,t)} = T_m - A_s \exp (-\alpha x) \cos \{w(t - t_0 - \alpha x/w)\} \dots\dots\dots 5$

75 Where, A_s = daily temperature amplitude at $x = 0$ °C; t = time of the day in hours,
 76 and t_0 = time of maximum temperature at the surface. The temperature T_m can be
 77 calculated from the hourly material surface temperature average $T_{hss}^{\circ}C$ as:

78 $T_m = \sum_{m=1}^{24} (T_{hss}/24) \dots\dots\dots 6$

79 On 24 hour period, equation (5) can be written as:

80 $T_{(x,t)} = T_m A_s \exp (-\alpha x) \cos \left\{ (2\pi/24)(t - t_0 - 12 \alpha x/\pi) \right\} \dots\dots\dots 7$

81 Equation 7 reveals that variation in temperature with thickness of soil sample at
 82 any time depends on the thermal properties of the soil.

83

84 **Specific Heat Capacity:**

85 Specific heat capacity of a substance is the quantity of heat required to raise the
 86 temperature of unit mass (kg) of the substance through unit temperature (1° C or
 87 1k). **It is observed experimentally** that the quantity of heat (Q) received by a body
 88 is proportional to its mass (M) and temperature change ($\Theta_2 - \Theta_1$) and also, depend
 89 on the nature of the material making the body. Mathematically, it is expressed as:

90 $Q \propto m (\Theta_2 - \Theta_1) \dots\dots\dots A1$

91 $Q = mc (\Theta_2 - \Theta_1) \dots\dots\dots A2$

92 Also, $C = Q / m (\Theta_2 - \Theta_1)$ A3

93 Where Q is the quantity of heat, m is the mass of the samples (body) in kg, $(\Theta_2 -$
94 $\Theta_1)$ is the temperature change in **0C** or **k**, C is the constant of proportionality which
95 depends on the nature of the body (Okeke and Anakoha, 1995). The unit of C is
96 joules per kg per Kelvin (**J/kg/k**).

97 Heat gained by calorimeter + sample + cold water =

98 $M_c C_c (\theta_3 - \theta_1) + M_s C_s (\theta_3 - \theta_1) + M_{cw} C_w (\theta_3 - \theta_1)$ A4

99 Heat lost by the hot water = $M_{nw} C_w (\theta_2 - \theta_3)$ A5

100 Equating eqn A4 and A5 gives the working equation for specific heat capacity, that
101 is,

102 $M_{nw} C_w (\theta_2 - \theta_3) = M_c C_c (\theta_3 - \theta_1) + M_s C_s (\theta_3 - \theta_1) + M_{cw} C_w (\theta_3 - \theta_1)$ A6

103 $C_s = \frac{M_{nw} C_w (\theta_2 - \theta_3) - [M_c C_c + M_{cw} C_w] (\theta_3 - \theta_1)}{M_s (\theta_3 - \theta_1)}$ A7

104 **Thermal Conductivity:** thermal conductivity is defined as the coefficient which
105 multiplies the temperature gradient to give the rate of heat transfer by conduction
106 expressed in heat energy crossing unit area in unit time (Frank and David, 1996).
107 It is given as $K = q''_x / (\Theta T / \Theta X)$. When the steady state has been attained the rate at
108 which heat is conducted across the soil samples disc is equal to the rate at which it
109 is emitted from the exposed surfaces of the metal slab C . If K is the thermal
110 conductivity of the soil samples disc, D its diameter, and d its thickness, and the
111 readings of the thermometers T_1 and T_2 in the steady state are Θ_1 and Θ_2 °C, then
112 the rate at which heat is conducted across the disc of soil samples is

113 $k \cdot \frac{\pi D^2}{4} \cdot \left(\frac{\theta_1 - \theta_2}{d} \right) \text{-----} \text{ (a)}$

114 if the mass of the metal slab C is M , its specific heat c , and the rate of cooling
 115 at θ_2 c is $\left(\frac{d\theta}{dt} \right)_2$ (obtained by drawing a tangent to the cooling curve at θ_2), then
 116 the rate of loss of heat from the lower face and the sides of the slab C is

117 $M c \left(\frac{d\theta}{dt} \right)_2 \text{-----} \text{ (b)}$

118 Hence equating (a) and (b) we have $k \cdot \frac{\pi D^2}{4} \cdot \left(\frac{\theta_1 - \theta_2}{d} \right) = M c \left(\frac{d\theta}{dt} \right)_2 \text{-----} \text{ (c)}$

119 from which k may be determined (Tyler,2005). Since; by Newton's law of cooling
 120 the rate of loss of heat is proportional to the excess temperature of a body over that
 121 of its surroundings, equation (c) above may be written

122 $k \cdot \frac{\pi D^2}{4} \cdot \left(\frac{\theta_1 - \theta_2}{d} \right) = \text{const.} (\theta_2 - \theta_0)$ where θ_0 is the air temperature (Tyler,2005).

123 Hence if for a specimen of another material of thermal conductivity k' and
 124 thickness d' , the steady state temperatures are θ_1' and θ_2' , a comparison of the
 125 thermal conductivities of the two specimens can be obtained without the necessity
 126 of proceeding with the second part (cooling curve) of the experiment.

127 Thus; $\frac{k}{k'} = \frac{d(\theta_2 - \theta_0)(\theta_1' - \theta_2')}{d'(\theta_2' - \theta_0)(\theta_1 - \theta_2)}$

It follows that, for a prescribed temperature gradient, the conduction heat flux increases with increasing thermal conductivity (Frank and David, 1996).

Heat conduction takes place only if there is a ~~temperature~~ difference ~~in temperature~~. Indeed, it is found experimentally that the rate of heat flow through a substance is proportional to the difference in temperature between its ends (Douglas, 1991). At steady state the heat conducted across the soil sample is equal to the rate at which it is emitted from the exposed surface (Ekpe et al, 1996). In general, the thermal conductivity of a solid is larger than that of a liquid, which is larger than that of a gas (Frank and David, 1996).

METHOD

Sample Collection and Preparation:

Soil samples ~~used for~~involved in the experiments were collected from three landforms in Akwa Ibom State. The landforms are: Beach Ridge Sand (BRS), Coastal Plane Sand (CPS) and Sandstone/Shale Hill Ridges (SHR) the soil samples were collected at depths of 0 – 15cm beneath the earth surface and put in different labeled containers. They were then air dried in the Physics laboratory, University of Uyo, Nigeria to drive away the moisture content. With some water, the soil samples were made wet such that they could be molded into the desired shape. Each of the samples was molded into a disc shape using a plastic ring designed for that purpose. The samples were afterwards dried in the ground or floor to solidify and then were stored in their respective containers rightly labeled. Six different soil samples were collected; locations and sources of collection are as shown in the table 1.

Table 1: Landforms and source of soil samples.

Landforms	Location
Beach Ridge Sand (BRS 1)	Ikot Ibok, Eket LGA
Beach Ridge Sand (BRS 2)	Ikot Akpan Mkpe, Onna LGA
Coastal Plain Sand (CPS 1)	Ikot Akan, Nsit Ubium LGA
Coastal Plain Sand (CPS 2)	Uniuyo Annex, Uyo LGA
Sandstone/Shale Hill Ridges (SHR 1)	Ikpe Ikot Nkon, Ini LGA
Sandstone/Shale Hill Ridges (SHR 2)	Ntak Inyang, Itu LGA.

Measurement of specific heat capacity:

The following were used during the analysis: weighing balance, thermometer, calorimeter, heat source, beaker, water, stop clock, soil samples (solid), thread, and logging material (Tyler, 2005). The calorimeter with stirrer was weighed and its mass recorded as M_c . The solid was put into the calorimeter and weighed as M_1 then the calorimeter was half filled with water. The calorimeter and the mixture were weighed and the mass recorded as M_2 . The initial temperature of the mixture was taken as θ_1 ; the final temperature of the boiling water was taken as θ_2 , the hot water was poured into the calorimeter with the mixture and the change in temperature with change in time was recorded. The highest temperature of the mixture was recorded as θ_m . Then, the specific heat capacity can be calculated for each of the soil samples by using equation A7.

$$C_s = \frac{M_{nw} C_w (\theta_2 - \theta_3) - [M_c C_c + M_{cw} C_w] (\theta_3 - \theta_1)}{M_s (\theta_3 - \theta_1)} \dots\dots\dots A7$$

C_s = specific heat capacity of the sample

M_{nw} = mass of hot water ($M_3 - M_2$)

C_w = specific heat capacity of water

M_c = mass of calorimeter

C_c = specific heat capacity of calorimeter

M_{cw} = mass of cold water ($M_2 - M_1$)

M_s = mass of sample

θ_1 = initial temperature of mixture

θ_2 = temperature of the hot water

θ_3 = final temperature of the mixture

M_1 = mass of calorimeter + sample

M_2 = mass of calorimeter + mixture

M_3 = mass of calorimeter + mixture + hot water

180 **Calculations for specific heat capacity:**

181 Using the experimental result on table 2 and the working equation A7 for specific
182 heat capacity, the heat experimental values of c_s was calculated for all samples as
183 in CPS 1, which the results are shown in table 4.

184 $m_{nw} = 0.06850\text{kg}$

185 $m_c = 0.0545\text{kg}$

186 $m_{cw} = 0.02326\text{kg}$

187 $m_s = 0.02964\text{kg}$

188 $c_w = 4200\text{Jkg}^{-1}\text{k}^{-1}$

189 $c_c = 400\text{Jkg}^{-1}\text{k}^{-1}$

190 $\theta_1 = 29.5^{\circ}\text{C} + 275 + 275 = 302.5\text{k}$

191 $\theta_2 = 98.5^{\circ}\text{C} + 273 = 371.5\text{k}$

192 $\theta_3 = 71.55^{\circ}\text{C} + 273 = 344.55\text{k}$

193 $\theta_2 - \theta_3 = 371.5 - 344.55 = 26.95\text{k}$

194 $\theta_3 - \theta_1 = 344.55 - 302.5 = 42.05\text{k}$

195

$$\underline{196} \quad C_s = \frac{[0.06850 \times 4200 \times 27.36] - [(0.0545 \times 400) + (0.02326 \times 4200)]41.64}{0.02964 \times 42.05}$$

$$\underline{197} \quad C_s = \frac{7871.472 - 4975.64688}{1.246362}$$

$$\underline{198} \quad C_s = \frac{2895.8251}{1.246362}$$

$$\underline{199} \quad C_s = 2323.422 \text{ J kg}^{-1} \text{ K}^{-1}$$

$$\underline{200} \quad C_s = 2323.42 \text{ J kg}^{-1} \text{ K}^{-1}$$

$$\underline{201} \quad \text{Error in } C_s \text{ is given as}$$

$$\underline{202} \quad \frac{\delta c_s}{c_s} = \frac{\delta m_{nw}}{m_{nw}} + \frac{\delta \theta}{\theta_2 - \theta_3} + \frac{\delta m_c}{m_c} + \frac{\delta \theta}{\theta_3 - \theta_1} + \frac{\delta m_{cw}}{m_{cw}} + \frac{\delta m_s}{m_s}$$

$$\underline{203} \quad \text{Error in mass, } m = 0.00001 \text{ kg}$$

$$\underline{204} \quad \frac{\delta c_s}{c_s} = \frac{0.00001}{0.06850} + \frac{0.50}{27.36} + \frac{0.00001}{0.05450} + \frac{0.50}{41.64} + \frac{0.00001}{0.02326} + \frac{0.00001}{0.02964}$$

$$\underline{205} \quad = 0.00015 + 0.01827 + 0.00018 + 0.01201 + 0.00043 + 0.00034$$

$$\underline{206} \quad \frac{\delta c_s}{c_s} = 0.03138$$

$$\underline{207} \quad \delta c_s = 2323.4222 \times 0.03138$$

$$\underline{208} \quad \delta c_s = 72.908989$$

$$\underline{209} \quad \therefore c_s = (2323.42 \pm 72.91) \text{ J kg}^{-1} \text{ K}^{-1}$$

Table 2: Experimental values of each sample for the determination of specific heat capacity.

Landforms / Samples	M_c (kg)	M_s (kg)	M_{cw} (kg)	M_{nw} (kg)	θ_1 °C	θ_2 °C	θ_3 °C
BRS 1	0.0545	0.02556	0.02731	0.06238	29.5	98.5	69.58
BRS 3	0.0545	0.04294	0.02587	0.05985	29.5	98.5	67.23
CPS 1	0.0545	0.02964	0.02326	0.06850	29.5	98.5	71.55
CPS 3	0.0545	0.02980	0.02021	0.07919	29.5	98.5	74.48
SHR 1	0.0545	0.03322	0.02766	0.04254	29.5	98.5	61.14
SHR 3	0.0545	0.03810	0.02834	0.05230	29.5	98.5	60.64

Also, $C_w = 4200 \text{ J kg}^{-1} \text{ K}^{-1}$ and $C_c = 400 \text{ J kg}^{-1} \text{ K}^{-1}$ while Θ is in °K; by putting the above data in table 2 into equation 8, we have the results in table 3. We find that different materials require different quantities of heat to raise the temperature of a given mass of the material through a specified number of degrees. Different materials absorb energy in different ways (Hewitt, 1985).

Measurement of thermal conductivity:

The following were used during the experiment: Lee's disc apparatus, thermometers, steam can, vernier caliper, strings, and retort stand with clamp, heat source and rubber tubing's. The apparatus was suspended as shown in figure 1 below and with the flat surfaces of the discs horizontal. Steam is passed through the cylinder A, and the temperatures indicated by the two thermometers T_1 and T_2 are read when the steady state has been reached 30-60 minutes. T_1 and T_2 are then interchanged, and their temperatures again read when steady. The cylinder A is then removed and a Bunsen flame is allowed to play on the bottom surface of the slab C until T_2 records a temperature up to 10° C higher than that recorded in the steady state. It is now allowed to cool, and readings of the temperature are taken at ½ - minute intervals until the temperature falls to about 10° C below the steady state temperature. The diameter of the soil samples disc was measured, and its thickness found by screw gauge, the mass of the metal slab C was determined (Tyler, 2005).

236 **Calculations for thermal conductivity:**

237 The result for thermal conductivity was obtained using the working equation and
238 also the error analysis involved. The method used here was applied to obtain the
239 results for other samples as recorded in table 4 as in sample CPS 1.

240 Let the gradient be; $\frac{d\theta}{dt} = \frac{\theta_2 - \theta_1}{t_2 - t_1}$

241 $\theta_2 = 57.0^\circ\text{C} + 273 = 330\text{k}$ $t_2 = 135 \text{ seconds}$

242 $\theta_1 = 40.0^\circ\text{C} + 273 = 311\text{k}$ $t_1 = 1410 \text{ seconds}$

243 Hence, $\frac{d\theta}{dt} = \frac{(330 - 311)\text{k}}{(135 - 1410)\text{sec.}} = \frac{17.0\text{k}}{-1275\text{s}}$

244 $\frac{d\theta}{dt} = -0.01333\text{ks}^{-1}$

245 To calculate the thermal conductivity k, recall equation C.

246 $\frac{k\pi D^2}{4} \left[\frac{\theta_1 - \theta_2}{d} \right] = mc \frac{d\theta}{dt}$

247 Making k the subject of formula,

248 $K = \frac{mc \frac{d\theta}{dt}}{\frac{\pi D^2}{4} \left[\frac{\theta_1 - \theta_2}{d} \right]}$

249 $m = 0.52\text{kg}, c = 400\text{Jkg}^{-1}\text{K}^{-1}, \pi = 3.142, D = 0.0625\text{m},$

250 $d = 12.80 \times 10^{-3} \text{m}, \theta_1 = 94.0^\circ + 273 = 367 \text{K}$

251 $\theta_2 = 51.5^\circ \text{C} + 273 = 324.5 \text{K}, d\theta/dt = 0.01333 \text{K s}^{-1}$

252 Substituting the values to obtain k,

253
$$K = \frac{0.52 \times 400 \times 0.01333}{\frac{3.142 \times (0.0625)^2}{4} \left[\frac{367 - 324.5}{12.80 \times 10^{-3}} \right]} = \frac{2.77264}{10.18791}$$

254 $K = 0.272150028 \text{W/mK}$

255 $K \approx 0.272 \text{W/mK}$

256 Error in k is given as

257
$$\frac{\delta k}{k} = \frac{\delta d\theta/dt}{d\theta/dt} + \frac{2\delta D}{D} + \frac{\delta\theta}{(\theta_1 - \theta_2)} + \frac{\delta d}{d}$$

258 Error in gradient, $d\theta/dt = 0.00027$

259 Error in diameter, $D = \frac{0.01}{2} \text{cm} = 0.005 \text{cm} = 5 \times 10^{-5} \text{m}$

260 Error in temperature $\theta = \frac{1^\circ \text{C}}{2} = 0.05^\circ \text{C}$

261 Error in thickness, $d = \frac{0.001}{2} \text{cm} = 0.0005 \text{cm} = 5 \times 10^{-5} \text{m}$

262 $\therefore \delta k = k \left[\frac{\delta d\theta/dt}{d\theta/dt} + \frac{2\delta D}{D} + \frac{\delta\theta}{(\theta_1 - \theta_2)} + \frac{\delta d}{d} \right]$

$$= 0.272 \left[\frac{0.00027}{0.01333} + \frac{2 \times 5 \times 10^{-5}}{0.0625} + \frac{0.5}{42.5} + \frac{0.5 \times 10^{-5}}{12.8 \times 10^{-3}} \right]$$

$$= 0.272 [0.02025 + 0.0016 + 0.01176 + 0.00039]$$

$$= 0.272 \times 0.034$$

$$= 0.009248$$

$$\delta k = 0.009$$

$$\Rightarrow K = (0.272 \pm 0.009) \text{ W/mk}$$

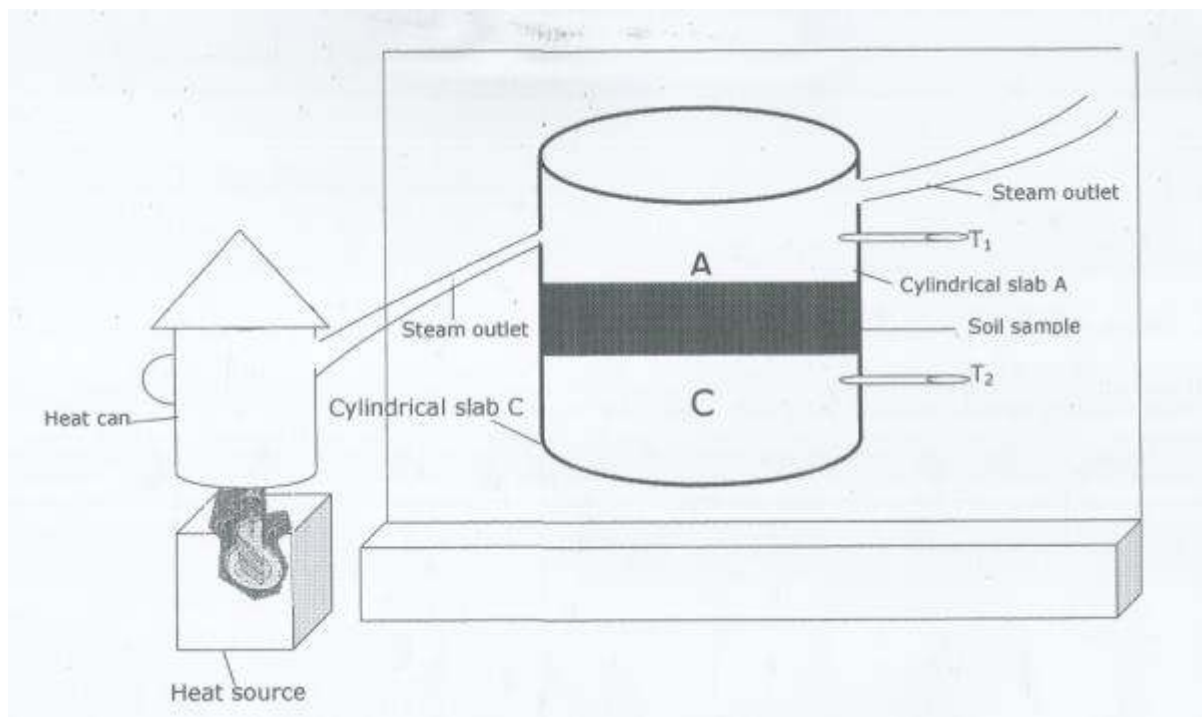


Figure 1: Determination of thermal conductivity of soil samples by Less' Disc method

Results and Discussion:

The results of the diameter of the soil samples disc were measured as 0.0625m;

The thickness of the soil samples disc was $12.80 \times 10^{-3}\text{m}$;

The mass of the metal slab C was 0.05254kg;

Specific heat capacity of metal C (from table) is $400\text{Jkg}^{-1}\text{k}^{-1}$

Table 3: Reading of thermometers in steady state.

	Upper temperature $T_1 (0^\circ \text{C})$	Lower temperature $T_2 (0^\circ \text{C})$
Before interchanging	92.50	52.00
After interchanging	95.50	51.00
Mean temperature	94.00	51.50

The results for the thermal conductivity and specific heat capacity was obtained as show in table below.

Table 4: Specific Heat Capacity and Thermal Conductivity of soil Samples.

Landforms	Specific Heat Capacity ($\text{Jkg}^{-1}\text{k}^{-1}$)	Thermal Conductivity (W/mk)
BRS 1	1964.54	0.333
BRS 2	1813.64	0.451
CPS 1	2323.42	0.272
CPS 2	2380.21	0.331
SHR 1	2197.36	0.409
SHR 2	3313.24	0.404

291 **Table 5:** Showing Results of the Calculated $C_R - K_R$ for each soil Sample.

Landforms	C (Jkg ⁻¹ k ⁻¹)	K(W/mk)	C_R	K_R	$d=C_R-K_R$	d^2
BRS 1	1964.54	0.333	2.00	3.00	-1.00	1.00
BRS 2	1813.64	0.451	1.00	6.00	-5.00	25.00
CPS 1	2323.42	0.272	4.00	1.00	3.00	9.00
CPS 2	2380.21	0.331	5.00	2.00	3.00	9.00
SHR 1	2197.36	0.409	3.00	5.00	-2.00	4.00
SHR 2	3313.24	0.404	6.00	4.00	2.00	4.00

292 $\sum d^2 = 52.00$

293 Using the value of specific heat capacity C and thermal conductivity k, to obtained
 294 Pearson's correlation coefficient $\gamma = 1 - \frac{6\sum d^2}{n(n^2-1)}$ (Dass, H. k; 2006); where n = 6
 295 (number of soil samples), $d^2 = 52$, but $C_R - K_R$ are correlation coefficient of specific
 296 heat capacity (C) and thermal conductivity (K), read from correlation table
 297 respectively.

298 Thus, $\gamma = 1 - \frac{6\sum d^2}{n(n^2-1)} = 1 - \frac{6 \times 52}{6(6^2-1)}$
 299 $= 1 - \frac{(312)}{6(35)} = 1 - \frac{(312)}{210} = 1 - 1.4857$
 300 $= -0.4857$

301 By using the analysis of variance (ANOVA),

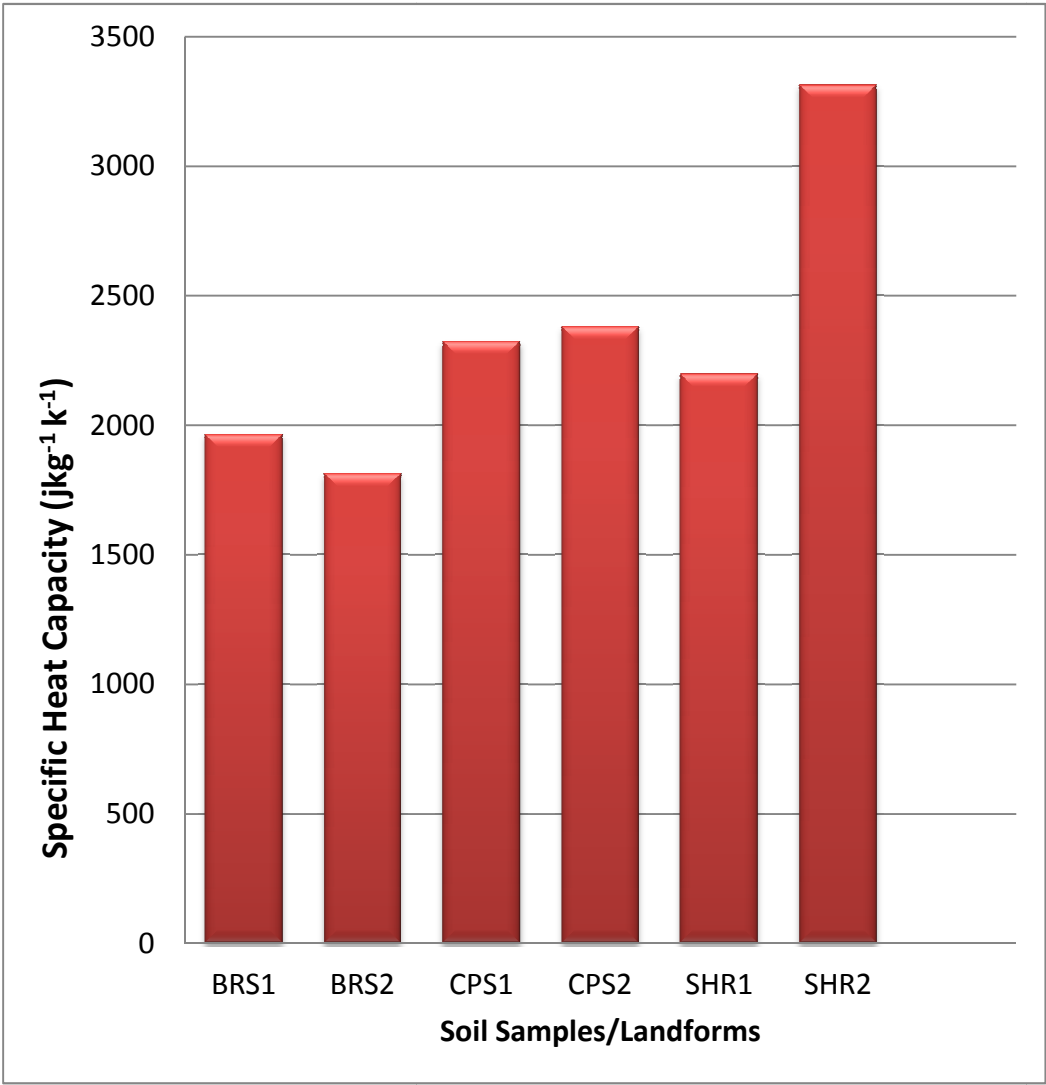
302 Null hypothesis (H_N): $C = K$; if $\gamma_{cal} > \gamma_{tab}$

303 Alternative hypothesis (H_A): $C \neq K$; if $\gamma_{cal} < \gamma_{tab}$

304 Where γ_{cal} = calculated value of γ and γ_{tab} = value of γ from correlation table. From
 305 correlation table (Gerald and Brian; 2003); with 6 degree of freedom γ_{tab} at $\alpha =$
 306 0.05 and $\gamma_{tab} = 0.8860$.

307 Since $\gamma_{cal} = 0.4857 < \gamma_{tab} = 0.8860$, we upheld the alternative hypothesis and
 308 concluded that there is no significant different in the C values of the three landform
 309 observed in Akwa Ibom State. The result of the measurement between the specific
 310 heat capacity and thermal conductivity is shown in figure 2 and 3.

311



312

313 **Figure 2:** Measurement of Specific Heat Capacity.

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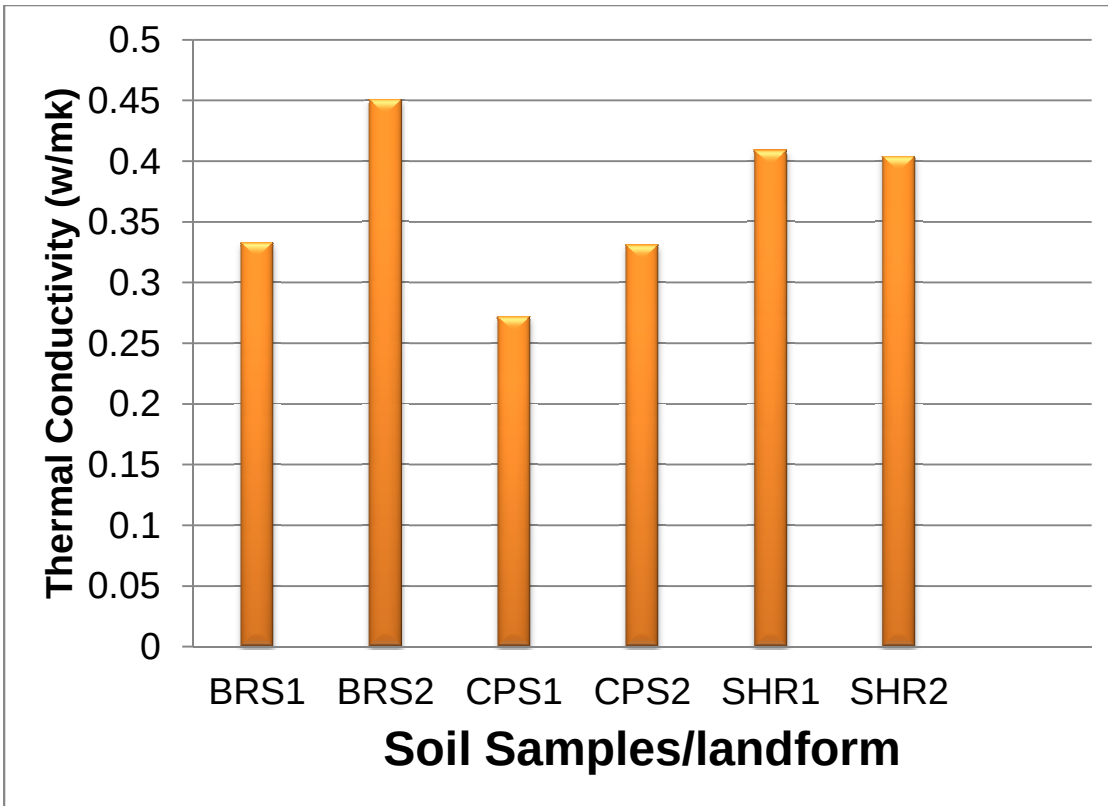


Figure 3: Measurement of Thermal Conductivity.

SUMMARY AND CONCLUSION

Different amounts of heat are absorbed by blocks of the same material if their mass is different and their temperature change is the same, if their mass is the same and their temperature change is different, or if they have different masses and undergo different temperature changes (Frederick, 1990).

From table 4, sample SHR have the higher thermal conductivity closely followed by BRS and CPS. This shows that samples SHR tend to conduct heat at a higher rate than BRS and CPS. Therefore, it can be said that specific heat capacity of the soil increases with a corresponding increase in thermal conductivity of the soil samples and vice versa as shown in the figures above. The results also reveal that they are an increase in specific heat capacity of SHR2. In order to increase the temperature of an object one must increase the thermal energy of its molecules. We can do this by letting heat flow into the object from hotter object (Frederick, 1977). Evidently, the larger the object to be heated, greater amounts of heat that must be supplied (Frank, 1983). In a tropical region like Africa with a high level of incident solar radiation like Nigeria, rocks samples

like those used for these work with high SHC low thermal conductivity is recommend for the design of civil or construction work.

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