

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

4
5 **ABSTRACT**

6 The thermal conductivity (K) and ^{up}specific heat capacity (C) of some samples
7 collected from three major landforms in Akwa Ibom State, Nigeria; namely Beach
8 Ridge Sand (BRS), Coastal Plane Sand (CPS), Sandstone/Shale Hill Ridges (SHR)
9 were measured. Results show that an increase in C of SHR and BRS samples taken
10 from different locations gives rise to decrease in K. The C of the area under study
11 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
12 conductivity was between the range $0.272 \text{ Wm}^{-1} \text{ K}^{-1}$ to $0.451 \text{ Wm}^{-1} \text{ K}^{-1}$. The C of the
13 soil samples has great effect on crop and construction works.

14 **KeyWords:** Thermal conductivity, Specific heat capacity, Soil and Coastal plane
15 sand.

16
17 **INTRODUCTION**

18 The study of soil properties is very important and useful to determine the
19 soil thermal conductivity. The uppermost soil layer of the earth's crust provides
20 support and nutrients for plant growth. Heat conduction is the transfer of heat from
21 one part of the body at high temperature to another part of the same body at low
22 temperature. The conduction process takes place at the molecular level and
23 involves the transfer of energy from the more energetic molecules to those with
24 lower energy level. Heat conduction in many materials can be visualized as the
25 result of molecular collision (Douglas, 1991). The conduction of heat occurs only
26 if there is a difference in temperature between two parts of the conducting medium
27 (Raymond and Jerry, 1992). Heat flow through any soil depends on the thermal
28 properties of the soil. Variation in temperature with thickness of the soil
29 determines whether the soil can be used as heat source. The prediction of
30 temperature at various thicknesses at any given time of the day throughout the year
31 is an important tool in the design of a construction work. Thermal properties of soil
32 samples involve many variables which may be complicated. Such variables include
33 the soil texture, structure and composition parameters. Similar studies of soil
34 properties in recent years include comparison of the thermal properties of brick
35 samples for a passively cooled building design (Akpabio and Ekpe, 1998) and

thermal response of different rock samples for a passively cooled building design (Akpabio *et al*, 2004).

THEORY

Soil temperature 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 is electromagnetic waves containing a wide range of wavelengths. This 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). According to conservation law of thermodynamics, heat budget equation can be expressed as: Heat flow through the soil = Heat absorbed 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,

units

α = solar radiation absorptivity,

I = intensity of solar radiation,

ϵ = long-wave emissivity of the surface and

link between ΔR and T_s

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 as:

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

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

please define better α and α_m

65 $T(x, t) = a_0 + \sum_{m=1}^{\infty} \{a_m \exp[i(m\omega t + \alpha mx)]\} \dots\dots\dots 3$

66 where $\alpha_m = (m\omega\rho C/2k)^{1/2}(1-i)$ where C is the specific heat capacity, ρ is the
67 density of the soil sample, and $\omega = 2\pi/T$ in which T is the period. The real part of
68 the equation (3) can be expressed as:

69 $T(x, t) = a_0 + \sum \{a_m \exp(-\alpha mx) \cos(m\omega t - \alpha mx)\} \dots\dots\dots 4$

70 Equation (4) can be modified as:

71 $T(x, t) = T_m - A_s \exp(-\alpha x) \cos \{w\omega(t - t_0 - \alpha x/\omega w)\} \dots\dots\dots 5$

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

75 $T_m = \sum_{m=1}^{24} (T_{hss}/24) \dots\dots\dots 6$

76 On ^a24 hour period, equation (5) can be written as:

77 $T(x, t) = T_m A_s \exp(-\alpha x) \cos \left\{ (2\pi/24)(t - t_0 - 12\alpha x/\pi) \right\} \dots\dots\dots 7$

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

80

81 **Specific Heat Capacity:**

82 Specific heat capacity of a substance is the quantity of heat required to raise the
83 temperature of unit mass (kg) of the substance through unit temperature (1°C or
84 1K). It is observed experimentally that the quantity of heat (Q) received by a body
85 is proportional to its mass (M) and temperature change ($\Theta_2 - \Theta_1$) and also, depends
86 on the nature of the material making the body. Mathematically, it is expressed as:

87 $Q = MC(\Theta_2 - \Theta_1) \dots\dots\dots 8$

88 Also, $C = Q / M(\Theta_2 - \Theta_1) \dots\dots\dots 9$

89 where Q is the quantity of heat, m is the mass of the samples (body) in kg, ($\Theta_2 - \Theta_1$)

90 is the temperature change in $^\circ\text{C}$ or K, C is the constant of proportionality which

91 depends on the nature of the body (Okeke and Anakoha, 1995). The unit of C is
 92 $\text{Jkg}^{-1}\text{K}^{-1}$.

93 Heat gained by calorimeter + sample + cold water =

94 $M_c C_c (\theta_3 - \theta_1) + M_s C_s (\theta_3 - \theta_1) + M_{cw} C_w (\theta_3 - \theta_1) \dots \dots \dots 10$

95 Heat lost by the hot water = $M_{nw} C_w (\theta_2 - \theta_3) \dots \dots \dots 11$

96 Equating 10 and 11 gives the working equation for specific heat capacity:

97 $M_{nw} C_w (\theta_2 - \theta_3) = M_c C_c (\theta_3 - \theta_1) + M_s C_s (\theta_3 - \theta_1) + M_{cw} C_w (\theta_3 - \theta_1) \dots \dots \dots 12$

98 The specific heat capacity is then:

99 $C_s = \frac{M_{nw} C_w (\theta_2 - \theta_3) - [M_c C_c + M_{cw} C_w] (\theta_3 - \theta_1)}{M_s (\theta_3 - \theta_1)} \dots \dots \dots 13$

100 **Thermal Conductivity:** thermal conductivity is defined as the coefficient which
 101 multiplies the temperature gradient to give the rate of heat transfer by conduction
 102 expressed in heat energy crossing unit area in unit time (Frank and David, 1996). It
 103 is given by $K = q''_x / (\partial T / \partial X)$. When the steady state has been attained, the rate at
 104 which heat is conducted across the soil samples disc, it is equal to the rate at which
 105 it is emitted from the exposed surfaces of the metal slab C. If K is the thermal
 106 conductivity of the soil samples disc, D its diameter, d its thickness, and the
 107 readings of the thermometers T_1 and T_2 in the steady state are θ_1 and θ_2 ($^{\circ}\text{C}$),
 108 then the rate at which heat is conducted across the disc of soil samples is

109 $k \cdot \frac{\pi D^2}{4} \cdot \frac{(\theta_1 - \theta_2)}{d} \dots \dots \dots 14$

110 If the mass of the metal slab C is M , its specific heat C , and the rate of cooling
 111 at $\theta_2(^{\circ}\text{C})$ is $(\frac{d\theta_2}{dt})_2$ (obtained by drawing a tangent to the cooling curve at θ_2), then
 112 the rate of loss of heat from the lower face and the sides of the slab C is

113 $MC (\frac{d\theta_2}{dt})_2 \dots\dots\dots 15$

114 Hence equating (14) and (15) we have

115 $k \cdot \frac{\pi D^2}{4} \cdot (\frac{\theta_1 - \theta_2}{d}) = MC (\frac{d\theta_2}{dt})_2 \dots\dots\dots 16$

116 from which k may be determined (Tyler,2005). Since by Newton's law of cooling,
 117 the rate of loss of heat is proportional to the excess temperature of a body over that
 118 of its surroundings, equation (16) above may be written as:

119 $k \cdot \frac{\pi D^2}{4} \cdot (\frac{\theta_1 - \theta_2}{d}) = \text{const. } (\theta_2 - \theta_0)$ where θ_0 is the air temperature (Tyler,2005).

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

124 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 augments with increasing thermal conductivity (Frank and David, 1996).

Heat conduction takes place only if there is temperature difference. 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). In 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 bigger than that of a gas (Frank and David, 1996).

METHOD

Sample Collection and Preparation:

Soil samples 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 so 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 this purpose. The samples were afterwards dried on the ground or floor to solidify and were then stored in containers. Six different soil samples were collected; locations and sources of collection are shown in table 1.

Table 1: Landforms and source of soil samples.

Landforms	Location
Beach Ridge Sand (BRS 1)	IkotIbok, Eket LGA
Beach Ridge Sand (BRS 2)	IkotAkpanMkpe, Onna LGA
Coastal Plain Sand (CPS 1)	Ikot Akan, NsitUbium LGA
Coastal Plain Sand (CPS 2)	Uniuyo Annex, Uyo LGA
Sandstone/Shale Hill Ridges (SHR 1)	IkpeIkotNkon, Ini LGA
Sandstone/Shale Hill Ridges (SHR 2)	NtakInyang, Itu LGA.

Measurement of specific heat capacity:

The following laboratory equipments 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 was recorded as M_c . The solid was put into the calorimeter and weighed as M_1 and then the calorimeter was half filled with water. The calorimeter and the mixture were weighed and the mass was 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 was calculated for each of the soil samples using equation 13 where

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 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

Calculations for specific heat capacity:

177 Using the experimental result of table 2 and the working equation 13 for specific
178 heat capacity, the experimental values of C_s were calculated for all samples as
179 CPS 1, whose results are shown in table 4.

180 $M_{nw} = 0.06850\text{kg}$

181 $M_c = 0.0545\text{kg}$

182 $M_{cw} = 0.02326\text{kg}$

183 $M_s = 0.02964\text{kg}$

184 $C_w = 4200\text{Jkg}^{-1}\text{K}^{-1}$

185 $C_c = 400\text{Jkg}^{-1}\text{K}^{-1}$

186 $\theta_1 = 29.5^\circ\text{C} + 275 + 275 = 302.5\text{K}$

187 $\theta_2 = 98.5^\circ\text{C} + 273 = 371.5\text{K}$

188 $\theta_3 = 71.55^\circ\text{C} + 273 = 344.55\text{K}$

189 $\theta_2 - \theta_3 = 371.5 - 344.55 = 26.95\text{K}$

190 $\theta_3 - \theta_1 = 344.55 - 302.5 = 42.05\text{K}$

191

192 $C_s = \frac{[0.06850 \times 4200 \times 27.36] - [(0.0545 \times 400) + (0.02326 \times 4200)]41.64}{0.02964 \times 42.05}$

$$193 \quad C_s = \frac{7871.472 - 4975.64688}{1.246362}$$

useless

$$194 \quad C_s = \frac{2895.8251}{1.246362}$$

$$195 \quad C_s = 2323.422 \text{ J kg}^{-1} \text{ K}^{-1}$$

$$196 \quad C_s = 2323.42 \text{ J kg}^{-1} \text{ K}^{-1}$$

197 Error in C_s is given as :

$$198 \quad \frac{\delta C_s}{C_s} = \frac{\delta m_{nw}}{m_{nw}} + \frac{\delta \theta}{\theta_2 - \theta_3} + \frac{\delta m_c}{m_c} + \frac{\delta \theta}{\theta_3 - \theta_1} + \frac{\delta m_{cw}}{m_{cw}} + \frac{\delta m_s}{m_s}$$

199 Error in mass = 0.00001 kg

$$200 \quad \frac{\delta C_s}{C_s} = \frac{0.00001}{0.06850} + \frac{0.50}{27.36} + \frac{0.00001}{0.05450} + \frac{0.50}{41.64} + \frac{0.00001}{0.02326} + \frac{0.00001}{0.02964}$$

$$201 \quad = 0.00015 + 0.01827 + 0.00018 + 0.01201 + 0.00043 + 0.00034$$

$$202 \quad \frac{\delta C_s}{C_s} = 0.03138$$

$$203 \quad \delta C_s = 2323.4222 \times 0.03138$$

$$204 \quad \delta C_s = 72.908989 \text{ J kg}^{-1} \text{ K}^{-1}$$

$$205 \quad C_s = (2323.42 \pm 72.91) \text{ J kg}^{-1} \text{ K}^{-1}$$

206

207

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 $^{\circ}\text{C}$	θ_2 $^{\circ}\text{C}$	θ_3 $^{\circ}\text{C}$
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. Different materials absorb energy in different ways (Hewitt, 1985).

Measurement of thermal conductivity:

The following laboratory equipments 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. The apparatus was suspended as shown in figure 1, below and with the flat surfaces of the horizontal discs. Steam passes 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 after 30-60 minutes. T_1 and T_2 are then interchanged, and their temperatures are again read when steady state is reached. The cylinder A is then removed and a Bunsen flame is allowed to come in contact with 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 then allowed to cool, and readings of the temperature were taken at $\frac{1}{2}$ - minute intervals until the temperature drops to about 10°C below the steady state temperature. The diameter of the soil sample disc was measured, its thickness was found using a screw gauge and the mass of the metal slab C was determined (Tyler, 2005).

Calculations for thermal conductivity:

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

expression

which equation 16?

$$\frac{d\theta}{dt} = \frac{\theta_2 - \theta_1}{t_2 - t_1}$$

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

$$\theta_1 = 40.0^\circ\text{C} + 273 = 311\text{k} \quad t_2 = 1410 \text{ seconds}$$

$$\text{Hence, } \frac{d\theta}{dt} = \frac{(330-313)\text{k}}{(135-1410)\text{sec.}} = \frac{17.0\text{k}}{-1275\text{s}}$$

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

To calculate the thermal conductivity K, from equation 16

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

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

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

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

Substituting the values to obtain K,

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

useless

$$K = 0.272150028\text{W/mk}$$

$$K \approx 0.272\text{W/mk}$$

247 Error in k is given as

$$\underline{248} \quad \frac{\delta k}{k} = \frac{\delta d\theta/dt}{d\theta/dt} + \frac{2\delta D}{D} + \frac{\delta\theta}{(\theta_1 - \theta_2)} + \frac{\delta d}{d}$$

249 Error in gradient, $d\theta/dt = 0.00027 \text{ } ^\circ\text{C/s}$

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

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

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

$$\underline{253} \quad \delta k = k \left[\frac{\delta d\theta/dt}{d\theta/dt} + \frac{2\delta D}{D} + \frac{\delta\theta}{(\theta_1 - \theta_2)} + \frac{\delta d}{d} \right]$$

$$\underline{254} \quad = 0.272 \left[\frac{0.00027}{0.01333} + \frac{2 \times 5 \times 10^{-5}}{0.0625} + \frac{0.5}{42.5} + \frac{0.5 \times 10^{-5}}{12.8 \times 10^{-3}} \right]$$

useless

$$\underline{255} \quad = 0.272 [0.02025 + 0.0016 + 0.01176 + 0.00039]$$

$$\underline{256} \quad = 0.009248$$

$$\underline{257} \quad \delta k = 0.009 \text{ W/mK}$$

$$\underline{258} \quad \Rightarrow K = (0.272 \pm 0.009) \text{ Wm}^{-1}\text{K}^{-1}$$

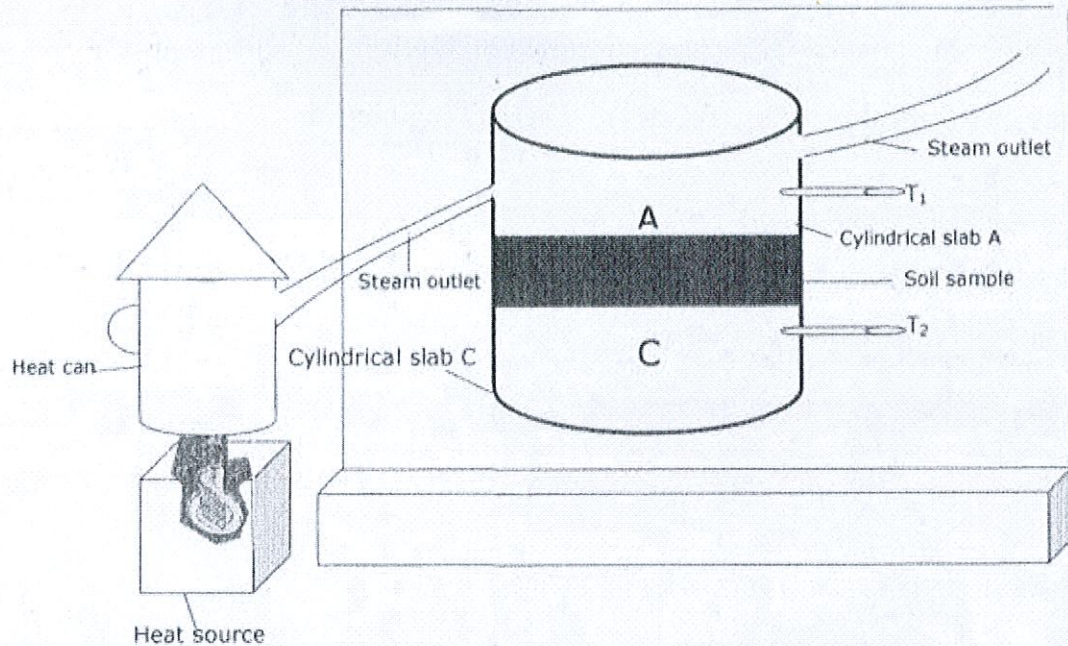


Figure 1: Determination of thermal conductivity of soil samples by Lee's Disc method

Results and discussion:

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

The thickness of the soil sample 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: Temperatures at steady state.

	Upper temperature T_1 ($^{\circ}\text{C}$)	Lower temperature T_2 ($^{\circ}\text{C}$)
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 were obtained as shown in table below.

{ SHR 2 highest specific heat capacity
 { BRS 2 highest thermal conductivity
 { BRS 2 lowest specific heat capacity
 { CPS 1 lowest thermal conductivity

272

273 **Table 4:** Specific heat capacity and Thermal conductivity of soil Samples.

Landforms	Specific heat capacity ($\text{Jkg}^{-1}\text{K}^{-1}$)	Thermal conductivity ($\text{Wm}^{-1}\text{K}^{-1}$)
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

Thermal diffusivity
 $D = \frac{\lambda}{\rho C}$
 m^2/s

274

good storage of heat in the range of soils

275

276 **Table 5:** Results of the calculated $C_R - K_R$ for each soil sample.

Landforms	C ($\text{Jkg}^{-1}\text{K}^{-1}$)	K ($\text{Wm}^{-1}\text{K}^{-1}$)	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

$\sum d^2 = 52.00$

277

278 Using the value of specific heat capacity C and thermal conductivity K, we
 279 obtained Pearson's correlation coefficient $\gamma = 1 - \frac{6\sum d^2}{n(n^2-1)}$ (Dass, H. k; 2006);
 280 where $n = 6$ (number of soil samples), $d^2 = 52$, but $C_R - K_R$ are correlation
 281 coefficient of specific heat capacity (C) and thermal conductivity (K).

282 Thus, $\gamma = 1 - \frac{6\sum d^2}{n(n^2-1)} = 1 - \frac{6 \times 52}{6(6^2-1)}$

283 $= 1 - \frac{(312)}{6(35)} = 1 - \frac{(312)}{210} = 1 - 1.4857$ useless

284 $= -0.4857$

285 By using the analysis of variance (ANOVA),

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

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

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

Since $\gamma_{cal} = -0.4857 < \gamma_{tab} = 0.8860$, we upheld the alternative hypothesis and concluded that there is no significant difference in the C values of the three landforms observed in Akwa Ibom State.

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 SHR samples have the higher thermal conductivity closely followed by BRS and CPS. This shows that SHR samples tend to conduct heat at a higher rate than BRS and CPS. It is also observed that increase in specific heat capacity of SHR and BRS samples correspond to decrease in thermal conductivity while that of CPS show the opposite. 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, the greater the amounts of heat that must be supplied (Frank, 1983). In a tropical region like Africa with a high level of incident solar radiation like in Nigeria, rock samples like those used for this work with high SHC and low thermal conductivity is recommended for the design of civil or construction work.

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