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INVESTIGATION OF THE VARIATION OF THE SPECIFIC HEAT CAPACITY OF LOCAL SOIL SAMPLES FROM THE NIGER DELTA, NIGERIA WITH MOISTURE CONTENT * †

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ABSTRACT

Results of an investigation of the variation, with moisture content, of the secific heat capacity of samples of three texturally different types of soil (clayey, sandy and sandy loam) obtained from the Niger delta area of Nigeria, are presented. The results show that the specific heat capacities of the soils studied, increase with moisture content. This increase is found to be linear for the entire range of moisture contents considered (0 - 25%), in the case of the sandy loam soil while for the clayey and sandy soils the specific heat capacity is found to increase linearly with moisture content up to about 15% after which the increase becomes parabolic. The rate of increase of specific heat capacity with moisture content appears to be highest in the clayey soil and lowest in the sandy soil. It is thought that the differences in the rates of increase of specific heat capacity with moisture content, observed for the soils, reflect the soils' water-retention capacities.

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INTRODUCTION

The lack of adequate knowledge of the physical properties of soils hinder proper agricultural development and control of soil erosion in an area such as the Niger delta in Nigeria. As part of an effort to study the physical properties of soils found in the Niger delta area of Nigeria, we have carried out measurements of the thermal properties of soil samples collected from that area. In this paper, we present the results of an investigation of the variation of the specific heat capacity of samples of three texturally different types of soil (clayey, sandy and sandy loam), collected from the area, with moisture content. Similar studies which have been carried out elsewhere include those of Ramonohan and Rao (1969), Gilhoyal and Triphi (1971) and Yadare and Saxena (1973).

EXPERIMENTAL PROCEDURE

A. Description of apparatus

The set up of the apparatus used in the investigation is shown in fig.1. It consists of a small cylindrical container or capsule made of brass, a chromel-alumel thermocouple, a hot water bath, a millivoltmeter and a beaker of ice. The cylindrical capsule is of diameter 1.7cm., has a depth of 3.8cm., and is sealed at one end while at the other end it is made water-tight by a removable cap. The thermocouple which was used to monitor the temperature of the brass capsule and its contents, was initially calibrated by means of a mercury-in-glass thermometer.

B. Determination of specific heat capacity

The method of cooling was used in the determination of the specific heat capacities of the soils examined. The method of cooling involves the plotting of cooling curves for a calorimeter (the brass capsule ,in our case) plus its contents when it contains equal volumes of (i) a hot liquid of known specific heat capacity and (ii) the substance (heated to some convenient temperature) whose specific heat capacity is to be determined. In the present investigation, water was used as the liquid of known specific heat capacity.
Fig.2 shows,schematically,cooling curves for water and a soil sample, from which the specific heat capacity of the soil sample can be determined using the following equation:

$$(M_s C_s + W_c)\left(\frac{dT}{dt}\right)_S = (M_w C_w + W_c)\left(\frac{dT}{dt}\right)_W \qquad (1)$$

where W_c is the thermal capacity of the calorimeter,

$\left(\frac{dT}{dt}\right)_S$ is the gradient of the cooling curve of the soil sample at point S in fig.2

$\left(\frac{dT}{dt}\right)_W$ is the gradient of the cooling curve for water at point W in fig.2

C_s is the unknown specific heat capacity of the soil sample

C_w is the specific heat capacity (kwown) of water

M_s is the mass of the soil sample

M_w is the mass of an equivalent volume of water

The method of cooling has the advantage that it eliminates errors due to heat losses to the surroundings.

C. Variation of specific heat capacity of soil samples with moisture content.

The collected samples of soil,as analysed by the hydrometer method, were found to be of three textural types,namely, clayey, sandy and sandy loam. Each sample,oven-dried initially for 24 hours,was packed into the brass capsule (shown in fig.1) and heated in a water bath to a temperature of about 70°C. This temperature was chosen in order to prevent vaporisation of water in the soil. Next, the capsule was cooled under forced convection and a cooling curve for it was plotted from which the specific heat capacity of the soil sample was determined using equation(1). After this,the moisture content of each of the soil samples was varied from 5% to 25% and the specific heat capacity determined for the sample at each moisture content.The results obtained for the various textural types of soil examined in the study are shown graphically in figs. 3,4 and 5.

DISCUSSION AND CONCLUSION

It is observed from fig.3 and 4 that the specific heat capacity of both the clayey and sandy soils increase linearly with moisture content up to about 15% moisture content. Thereafter, the increase is parabolic,with the curvature of the graph for clay directed upward while that for the sandy soil is directed downward. In the case of the sandy loam soil (fig.5), the specific heat capacity increases linearly with moisture content over the entire range of moisture contents considered (viz.0-25%) A comparison of the curves in figs.3 through 5, shows that the specific heat capacity increases most rapidly with moisture content in the case of the clayey soil and least in the case of the sandy soil. The rates of increase deduced from the linear portions of the graphs are 88,71,and 62 $J\ kg^{-1}\ K^{-1}$ per percentage of moisture content,for the clayey, sandy loam and sandy soils respectively.
It is generally expected that the presence of water in a soil will cause an increase in the amount of heat required to raise the temerature of the soil since the total composite mass of the soil to be heated increases as its moisture content is increased. However,the differences in the rates of increase of specific heat capacity observed for the soils examined here, may be attributed to differences in the soils' water-retaining capacities. On the basis of this assertion, it appears that the clayey soil has the largest water-retention capacity. This is supported by the fact that clay is observed to have greater cohesion than sandy and sandy loam soils owing to the retention of more moisture films in clay.
The results of the study show that moisture content influences the specific heat capacity of the soils examined. The result are in agreement with those of other workers (eg. Ramonohan and Rao,1969). A soil sample with high specific heat capacity is less likely to exhibit rapid temperature changes as the heat flux incident on it changes. Thus the results of the study indicate that wet soil would respond rather slowly to changes in the heat flux incident on it.

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FIGURE CAPTIONS

Fig. 1 Schematic diagram of the apparatus for the determination of specific heat capacity.
Fig. 2 Cooling curves for water and soil.
Fig. 3 Variation of specific heat capacity with moisture content.
Fig. 4 Variation of specific heat capacity with moisture content.
Fig. 5 Variation of specific heat capacity with moisture content.

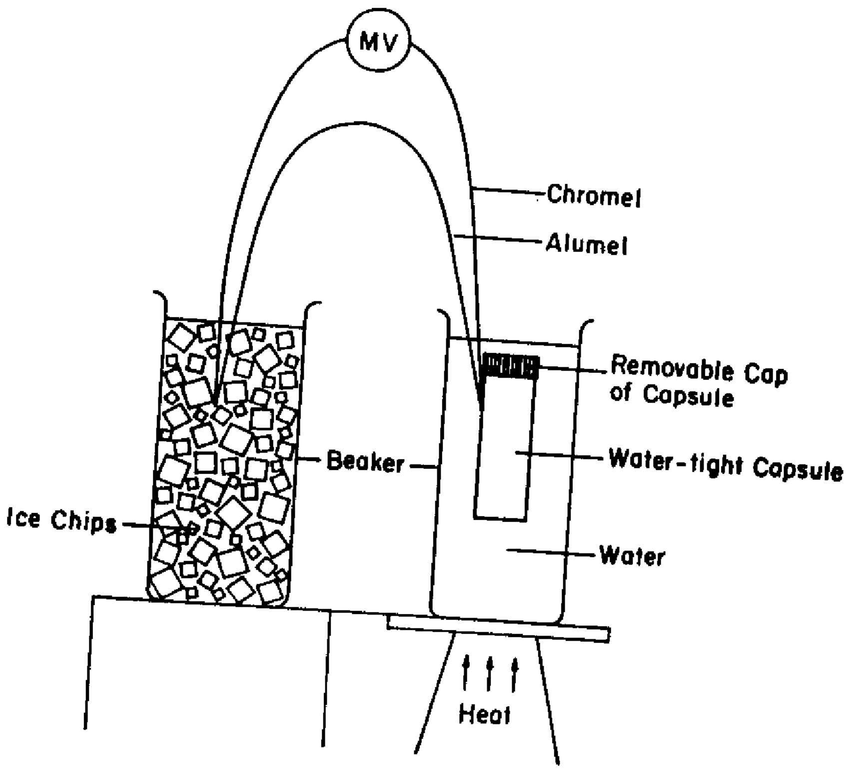
MV
Chromel
Alumel
Removable Cap of Capsule
Beaker
Water-tight Capsule
Ice Chips
Water
Heat

Fig. 1

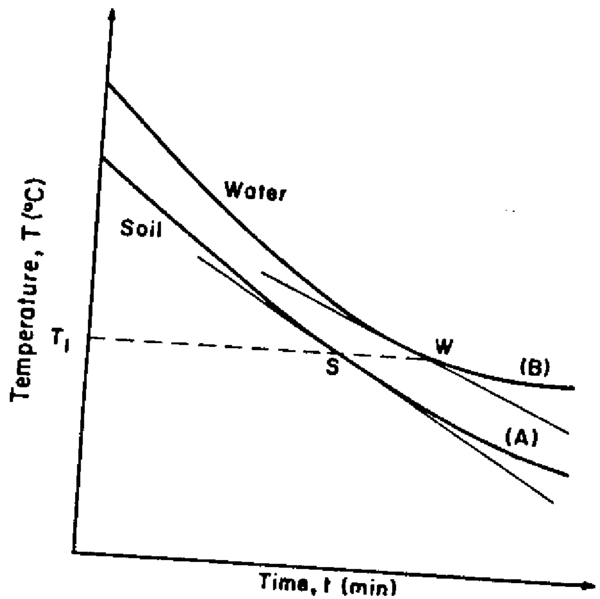
Temperature, T (°C)
Water
Soil
T_1
W
S
(B)
(A)
Time, t (min)

Fig. 2

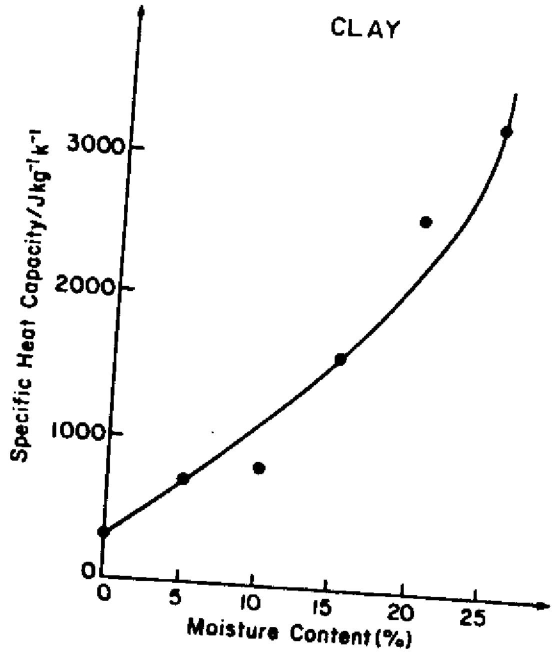
CLAY
Specific Heat Capacity/Jkg⁻¹k⁻¹
3000
2000
1000
0
0
5
10
15
20
25
Moisture Content (%)

Fig. 3

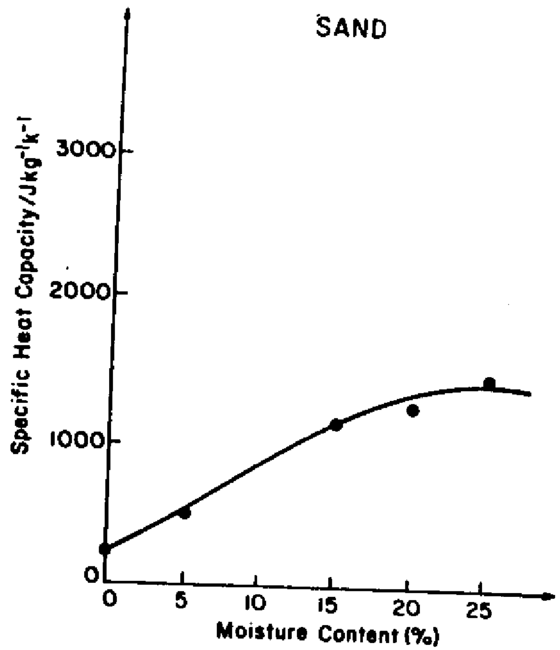
SAND
Specific Heat Capacity/Jkg⁻¹k⁻¹
3000
2000
1000
0
0
5
10
15
20
25
Moisture Content (%)

Fig. 4

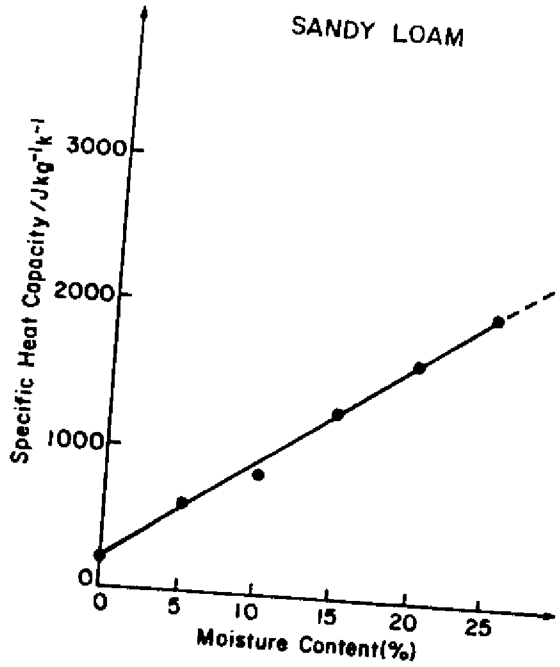
SANDY LOAM
Specific Heat Capacity /Jkg⁻¹k⁻¹
3000
2000
1000
0
0
5
10
15
20
25
Moisture Content(%)

Fig. 5