Bull. Fac. Agric., Cairo Univ.,53 (2002): 671-688.

PARTICIPATION OF SOIL PARTICLE SIZE FRACTIONS INTO SOIL TEMPERATURE PROFILES AND THERMAL PROPERTIES

(Received: 2.1.2002)

By

M.H.A. Ghali and S.A . Mohamed *

Soil Department ,Institute of Efficient Productivity, Zagazig University
**Soil and Water Department, Faculty of Agriculture, Suez Canal University, Ismailia*

ABSTRACT

A laboratory experiment was carried out on cylindrical columns equipped with temperature devices to investigate temperature profiles for separated soil particle fractions during incoming and outgoing heat flow processes. Three soil particle size fractions were separated from Kassasin loamy sand and Nubaria calcareous sandy loam soils. Temperatures were measured along the vertical dimension at the center of the soil column using copper-constant thermocouple wires and digital thermometer. Thermal conductivities, diffusivities, heat capacities were calculated for both investigated soils. Also, values obtained for determined soil particle size fractions heat capacities were compared with calculated ones by 3 different methods. Moreover, total and partial heat gain or loss for soil particle fractions were calculated. The effect of the soil particle size fractions; *i.e.*, their porosities on the flow of heat was examined.

It was found that the determined temperature fluctuations with depth for the loamy sand soil are lower than for the calcareous sandy loam soil. It was also found that the flow of heat along the soil depends on the apparent soil density and its size fractions, due to the variation in the thermal conductivity.

Total heat gained during 6 hours heating within the upper 20 cm for Nubaria calcareous sandy loam soil particle fractions having average diameters 4.175, 2.675 and 1.59 mm and total heat loss during 6 hours cooling from the upper 30 centimeters to the atmosphere were higher than those obtained for the corresponding fractions obtained for Kassasin loamy sand soil. This response occurred taking into consideration that the former soil fractions had lower apparent densities and higher $CaCO_3$ contents than the latter ones.

Fractionated heat loss or gain occurred during the first 1.5 hours generally exhibited the highest values and decreased with the increase in time. It was also noticed for both soils particle fractions that partial or total heat gain or loss generally increased as particle diameter decreased.

Key words: *conductivities, diffusivities, heat flow processes , partial heat gain or loss , soil temperature profiles, thermal heat capacities.*

1. INTRODUCTION

It is well known that thermal energy which reaches the soil surface is subjected to reflection, absorption and conduction. Conduction accounts almost exclusively for heat transmission in the soil. Generally it decreases as heat energy penetrates the soil. The speed with which heat is transferred in the soil, upward (cooling) and downward (heating), depends upon the existing temperature gradients and heat conductivity of the soil.

The thermal conductivity of a porous material depends greatly on its volumetric density. It increases as volumetric soil density increases. Eigenson, (1952); Van Wijk (1963); De Vries, (1963) and Campbell, (1985). Semmel *et al.* (1990) stated that heat conduction and thermal diffusivity should increase rapidly as soon as the dry soil particles are surrounded by water films enlarging their contact area. The formation of water films depends on soil water content and matric potential. The presence of water in the soil pores will lead to the application of Fourier's law which deals with multidisciplinary systems. Ghuman and Lal (1985) and Jury *et al.* (1991) found that clay soils had lower thermal conductivity values than sandy soils at all levels of water contents. Moreover, conductivity increased with increasing soil water content. This is explained by the fact that thermal conductivity of the air filling pores is much less than that of the solid constituents. Hadas (1977 a and b) stated that the thermal conductivity of a soil depends on its mineralogical composition, texture, water content and its particle shape, as well as their space arrangement. Nimmoc and Kstin, (1988) concluded that thermal conductivity of porous material depends greatly on moisture content.

Knowledge of simultaneous transfer of heat and moisture in soils near the soil surface is of great importance to meteorologists, soil scientists, and ecologists,(Johnson and Lowery 1985 and Parlange *et al*,.1998) They studied evaporative losses of soil water and its thermal regime, as well as the energy and mass exchange phenomena occurring at the soil surface. They concluded that effective thermal conductivity of porous material depends greatly on moisture content due to its very high value of heat capacity compared to the other two phases of soil constituents; namely, solids and air. Also, they calculated thermal diffusivity values for soils with different tillage practices representing different kinds of soil structure. Thermal diffusivity in the 5 to 15 cm soil depth was 20-25% higher in the untilled, than in the ploughed soil.

Some investigators were devoted to investigate the influence of thermal gradients in soil moisture transport, (Cary and Tylor, 1962 and Cassel *et al.*,1969). The rate of heating soil particles depends on particle heat capacity, size of particles and other properties. Very small particles can be heated more rapidly while larger particles absorb more heat than smaller ones. The thermal conductivity of granular materials increased with temperature and this may be explained by the fact that an increase in temperature is accompanied by an increase in heat conduction of the medium filling the spaces between the grains, and also by the intensification of radiant heat transfer within the granular material. Golovanov, (1969) investigated the dependence of upward and downward heat flow within the soil and temperature time functions on soil particle sizes.

The aim of the current study was to investigate the effect of two soil textures on temperature profiles and soil thermal conductivities, diffusivities and capacities. A second objective was to calculate partial and total heat gain or loss for particle size fractions per time and per depth.

2. MATERIALS AND METHODS

2.1. Experimental apparatus and procedure:

A laboratory experiment was carried out to investigate temperature distributions for two soil textures and three particle size fractions for each soil under heating and cooling cycles. An apparatus was constructed for this purpose, Figure (1). It consists of insulated hard PVC (70 cm long, 10 cm outside diameter and 9.5 cm inside diameter) column, heating unit, ice tank, 2 aluminum discs, 14 locations for the thermocouple wires, and temperature measuring devices. The outer surface of the soil column was insulated by 3 cm glass-wool mat to guarantee heat flow only in the vertical direction. A heat source, electric disc heater, was placed on the upper surface of the first aluminum disc. The diameter of the disc heater was about 100 mm and its power is 200 watt (220 volt and 10 ampere). The power supplied to the heater was controlled by a variac transformer. It provides a controllable constant heat flux at the top of the soil column. The electric power input to the heater was measured by an in-line digital watt-meter (accuracy ± 0.5%). Each one of the aluminum discs was 95 and 15 mm in diameter and thickness, respectively. The second aluminum disc was placed at the bottom of the soil column directly in contact with ice-water mixture.

Eight copper-constantan calibrated thermocouples, 0.4 mm in diameter, were inserted inside the test materials at the center of the column, Figure (1), to measure soil temperature at eight depths. Additional thermocouple was fixed at the back of each aluminum disc to measure its temperature. Furthermore, a grid of 25 thermocouples were distributed radially inside the soil column at 25 mm under the soil surface to be sure that radial heat flow is nearly eliminated. One thermocouple is used to measure temperature of ice-water mixture in the ice tank (heat sink) beside one of two thermocouples was fixed at the outer surface of the PVC soil column while the other was fixed at the surface of the insulating pad to calculate radial heat loss. The readings of the thermocouples were taken by a digital thermometer (accuracy ± 0.4 °C)

The total rate of heat generated from the heater (q_t) was transmitted by conduction in vertical and radial directions according to the following formula:

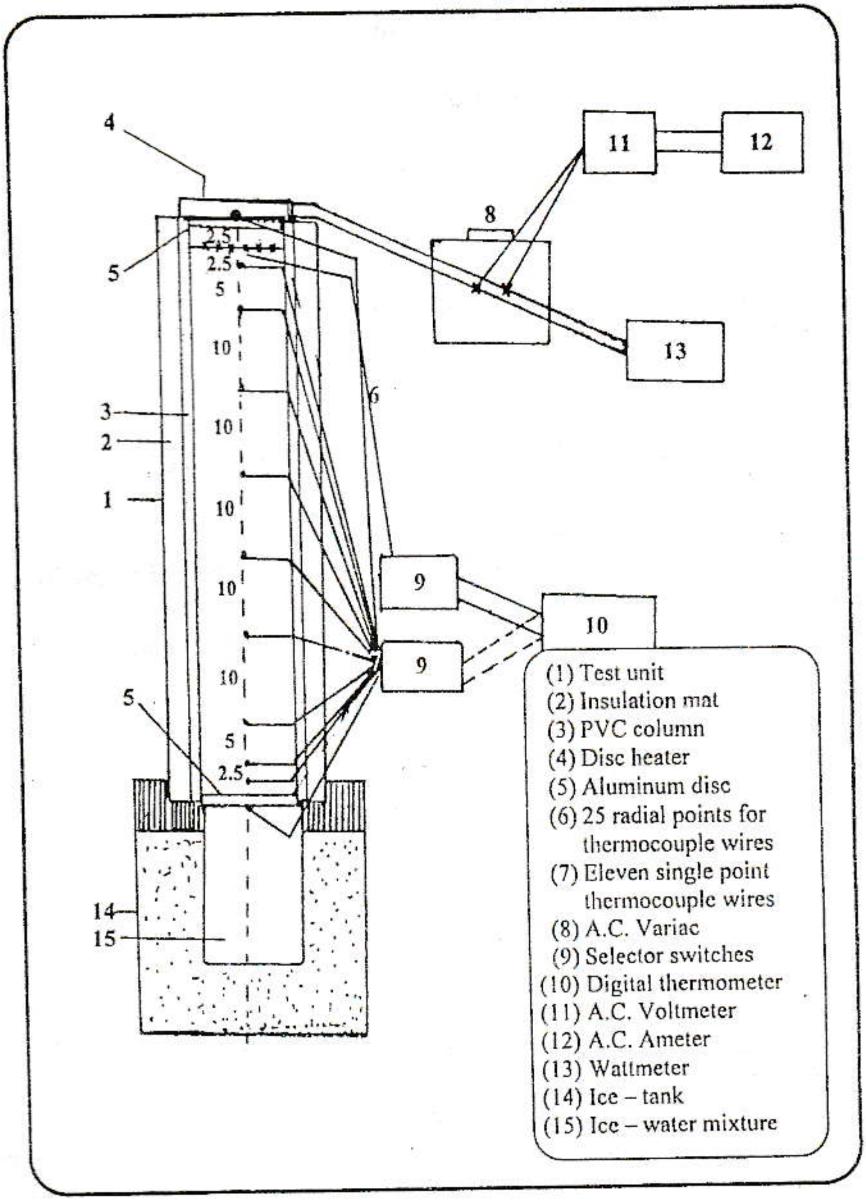

Fig. (1): Schematic diagram of the experimental apparatus and measuring devices.

$$q_t = q_{c,v} + q_{c,r} \qquad (1)$$

Where:

q_t = total heat input, W
$q_{c,v}$ = vertical heat flow, W
$q_{c,r}$ = radial heat flow, W

Due to the fact that the maximum heat loss by conduction in the radial direction, $q_{c,r}$ was about 0.05% of the total heat input, Eq (1) is rewritten as follows:

$$q_t = q_{c,v} \cong K_s A \frac{\Delta T}{\Delta X} \cong K_s (1\text{-}P) A \frac{\Delta T}{\Delta X} \qquad (2)$$

Where:

$q_{c,v}$ = Vertical heat follow, W
K_s = Thermal conductivity of the solid particles W/m°C.
A = Cross-sectional area of the soil column, m^2
ΔT = Temperature difference, °C
ΔX = Soil thickness, m
P = Porosity, %

If the thermal conductivity of the air in the soil pores is taken into consideration, Eq (1) can be rewritten as follows:

$$q_t = q_{c,v} = K_s (1\text{-} P)A \frac{\Delta T}{\Delta X} + K_a PA \frac{\Delta T}{\Delta X} \qquad (3)$$

Where K_a = thermal conductivity of air, 0.161 cal/cm. °c. sec, Black, (1965).

2.2. Preparation and analysis of soil sample:

Representative soil samples were collected from two different locations at 0-70 cm depths. The first soil sample was collected from Kassasin loamy sand soil located at 30 kilometers west of Ismailia city, north of Cairo-Ismailia desert road. The second soil sample was collected from Nubaria calcareous sandy loam soil located at 40 km south west of Alexandria at Cairo- Alexandria desert road. Soil samples were analyzed for particle size distribution as described by Gee and Bauder, (1986). O.M % and $CaCO_3$ % according to Page, (1982). Particle, and bulk densities were determined and total porosities were calculated as described by Klute, (1986). Table (1) shows some physical characteristics of the collected soil samples.

Table (1): Physical characteristics of the collected soil samples.

Soil property		Kassasin loamy sand soil	Nubaria calcareous sandy loam soil
Particle size distribution			
C.S	%	64.40	1.70
F.S.	%	20.00	78.10
Silt	%	3.70	9.10
Clay	%	11.90	11.10
CaCO3	%	1.90	36.20
O.M	%	0.85	0.54
Bulk density,	$g\ cm^{-3}$	1.57	1.33
Particle density,	$g\ cm^{-3}$	2.65	2.50
Porosity,	%	40.75	46.80
Aggregate size distribution			
MWD	**mm**	1.560	0.747
GMD	**mm**	0.189	0.111

Each air dry soil sample was placed on top of a series of sieves and shaken using vibrating shaker, Klute, (1986). After 5 minutes shaking period, the retained sample on each sieve and on the bottom pan was weighed and its percentage of the total sample weight was determined. The percentage retained on each sieve was multiplied by the average sieve hole diameter calculated from a sieve hole and the sieve hole above.

Three particle size fractions were chosen for each one of the two investigated soils. Each particle fraction was oven dried at 105°c and packed in a column at approximately equal field apparent densities. Each column was replicated three times. Each column was subjected to heating then cooling cycles. During heating cycle, temperature measurements were recorded at 30 minutes intervals for more than 6 hours. The heat input and heat sink were kept constant during the experiment. During cooling cycle, the power for the heater was switched off. Then, the heater and the adjacent aluminum disc were removed from the top of the soil column. Temperatures were recorded at 30 minutes intervals for more than 6 hours.

3. RESULTS AND DISCUSSION

Simultaneous heat flow parameters were calculated for the investigated soils using the formulae derived by Ghuman and Lal (1985). They are:

$Ln\,k = 0.028\ x\ -2.158,$

$Ln\,a = 0.028\ x\ -7.887,$ and

$Lnc = -0.003\ x\ -1.071$

Where : k is the thermal conductivity, mcal./s. cm ^{o}c;

a is the thermal diffusivity, cm^{2}/s.;

c is the thermal capacity, cal./g.^{o}c and

x is the sum of sand, silt and organic carbon in percentages.

Ghuman and Lal stated that these regression equations were deduced at 0.10 cm^{3} cm^{-3} water content for soils vary in texture from sandy loam to clay. The results obtained for the Kassasin loamy sand soil are 1.3946, 0.0045 and 0.2624 and for the Nubaria calcareous sandy loam soil are 1.4138, 0.0046 and 0.2620, respectively. Ghuman and Lal (1985) stated that thermal conductivity values for air dry soils did not appreciably vary, 0.70 to 0.60 mcal./s. cm ^{o}c for sandy and clayey soils, respectively, at zero percent volumetric water content. The obtained k values also did not appreciably vary, therefore confirming their conclusion although the obtained values are almost twice their values. They also stated that their k values tremendously increased as soil moisture content increased. In the mean time, as soil bulk density decreased, the thermal conductivity value became low.

The thermal capacities for both soils were calculated by 3 different methods: Method 1 is used by applying the formula of Ghuman and Lal (1985) as mentioned before. Method 2 is used by applying the formula C= k/a presented by Geiger (1965) using the calculated values of thermal conductivity (k) and thermal diffusivity (a) according to the equations given by Ghuman and Lal (1985). Method 3 is suggested by De Vries (1963) using the following equation: Cv= 0.46 Xm + 0.60 Xo + Xw, where Xm, Xo and Xw are the volume fractions of soil mineral matter, organic matter and water, respectively. The thermal capacities were also determined and the obtained results are given in Table (2). Method 1 used to calculate gravimetric or volumetric soil heat capacity, Cs or Cv, proved to be very close to the determined value for the Kassasin loamy sand soil, 0.2624 and 0.4120, respectively. However, method 2 is more suitable to calculate soil heat capacity for

Nubaria calcareous sandy loam soil, 0.2314 and 0.3077, respectively. The low determined Cs value obtained for the latter soil compared to the former one is probably related to its high $CaCO_3$%, Table (1).

To evaluate the effect of soil particle size fractions and calcium carbonate content on heat capacity, comparisons were made between determined and calculated values, Table (2). The data clearly show that all calculated Cs values by method 1 are higher than the determined ones, whereas all calculated Cs values by method 3 are lower than the determined ones. Moreover, the Cv values for the various particle size fractions calculated by method 1 or 3 for the Kassasin loamy sand soil are higher than the corresponding ones for the Nubaria calcareous sandy loam soil. In the mean time, the determined C values for the former soil are higher than the determined C values for the latter one. The wide variations between measured and calculated C values led to the suggestion that the determined C values for the various soil particle size fractions should be used. Moreover, it is noticed that as the diameter of particle size fraction for either soil decreased the measured C values increased. The major contribution of solid particles on soil heat capacity is related to its apparent density because of the increase in $CaCO_3$ content, Table (3), could not completely diminish the increase in C values. Therefore, the high bulk density of the loamy sand soil, led to its high C value and low k value, therefore, was responsible for the fact that it suffered from extreme temperatures. On the other hand, calcareous soils are considered cold ones, Geiger (1965). Hence, Nubaria calcareous sandy loam soil C,K and bulk density values should be carefully examined in order to evaluate their temperature status.

The data obtained for soil temperature profile during heating cycle for both soils proved that the upper 20 cm soil depth was susceptible to temperature accumulation with time due to the presence of heat source on the top of the soil column, Figure (2). Also, the lowest 18 cm soil layer was susceptible to heat loss with time due to the presence of heat sink, Figures (1 and 2). At these boundaries, the variation in temperature was around 1°C. Consequently, the intermediate 30 cms of the soil were not affected by heat source or sink.

During cooling cycle, the layer exposed to temperature loss to the atmosphere reached 30 cms for both soils. In the mean time, the effect of the deep heat sink also extended to the lowest 18 Cm.

Concerning the detailed study on temperature profiles for the various soil particle size fractions within the forementioned heating and

Table (2): Gravimetric heat capacity C_s, cal/g°c, volumetric heat capacity, C_v, cal/cm^3 °c and total porosities for soil and particle size fractions.

Soil and average particle diameter	Porosity %	ρ_b g cm^{-3}	Determined		Calculated					
					Method 1		Method 2		Method 3	
			C_s	C_v	C_s	C_v	C_s	C_v	C_s	C_v
Kassasin loamy sand soil	40.80	1.57	0.2403	0.3773	0.2624	0.4120	0.1961	0.3079	0.1739	0.2730
Avg. particle diameter (mm)										
4.175	38.87	1.62	0.2301	0.3728	0.3416	0.5534	—	—	0.1736	0.2812
2.675	38.11	1.64	0.2332	0.3824	0.3416	0.5602	—	—	0.1736	0.2847
1.590	36.60	1.68	0.2412	0.4052	0.3416	0.5739	—	—	0.1736	0.2916
Nubaria calcareous sandy loam soil	46.80	1.33	0.2331	0.3100	0.2620	0.3485	0.2314	0.3077	0.1843	0.2451
Avg. particle diameter (mm)										
4.175	43.6	1.41	0.2148	0.3029	0.3416	0.4817	—	—	0.1840	0.2594
2.675	42.4	1.44	0.2219	0.3195	0.3416	0.4919	—	—	0.1840	0.2650
1.590	40.0	1.50	0.2301	0.3452	0.3416	0.5124	—	—	0.1840	0.2760

Table (3): Distribution of $CaCO_3$% in different particle sizes of the tested soils.

Soil texture	$CaCO_3$% in different particle sizes						Total $CaCO_3$ %	% of the total $CaCO_3$					
	5.0	3.35	3.00	1.60	1.18	0.60		5.0	3.35	3.00	1.60	1.18	0.60
	mm							mm					
Kassasine loamy sand soil	0.12	0.19	0.25	0.39	0.48	0.52	1.90	6.31	10.00	13.16	20.53	22.63	27.37
Nubaria calcareous sandy loam soil	2.97	3.49	4.42	5.35	6.77	13.2	36.2	8.20	9.64	12.21	14.78	18.70	36.47

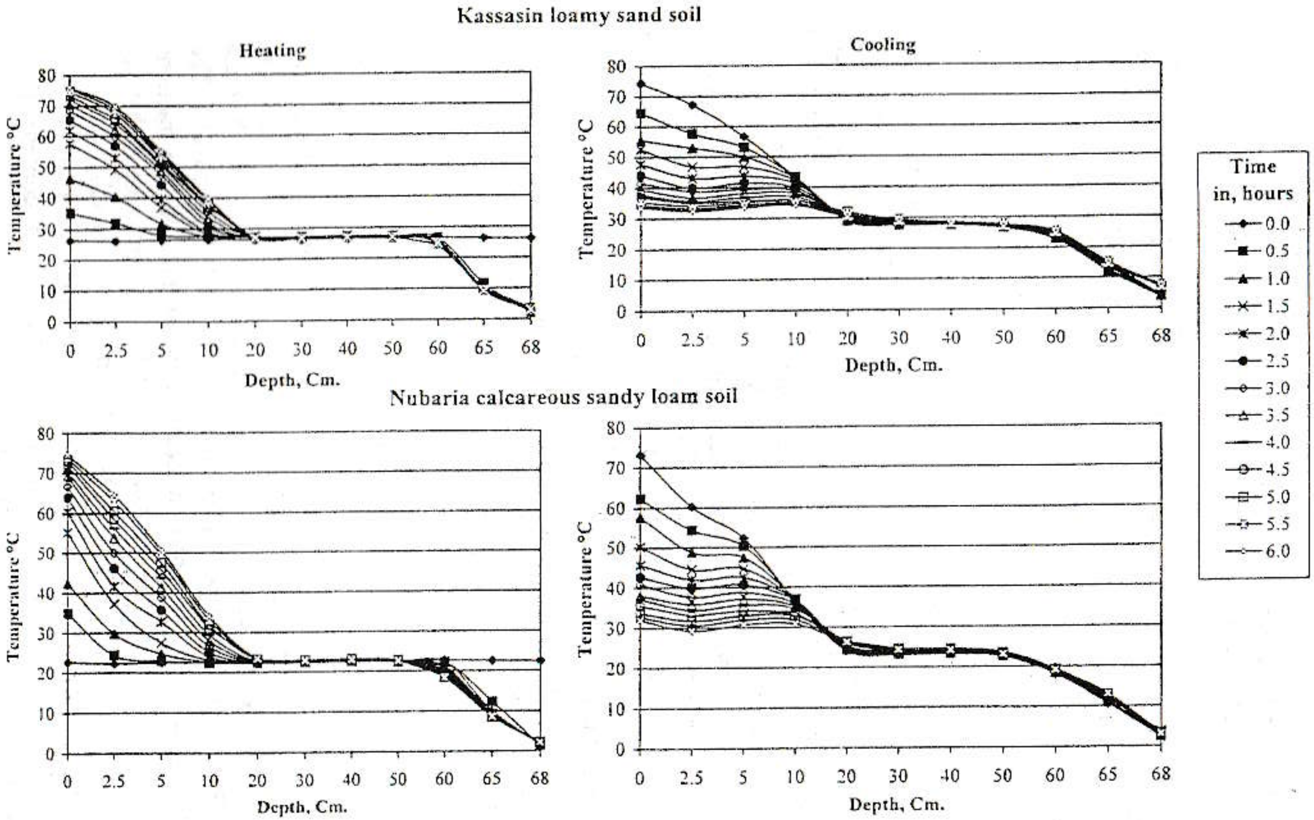

Fig. (2): Effect of heating and cooling cycles on temperature profiles at various depths and times for the studied soils.

cooling depths, the obtained results are presented in Tables (4 A and B), which clearly show during the heating cycle that the average initial temperatures, $T_{0\ hour}$, were 26.2, 20.5 and 25.2°C for Kassasin loamy sand soil particle size fractions having average diameters 4.175, 2.675 and 1.59 mm, respectively. The average final temperatures, $T_{6\ hours}$, became 40.1, 43.7 and 51.6°C, respectively. The average initial temperatures for Nubaria calcareous sandy loam soil particle size fractions having similar diameters to the forementioned ones were 27.2, 28.6 and 25.5. At 6 hours of the heating cycle, these values became 45.9, 55.6 and 54.7, respectively.

During the cooling cycle, average $T_{0\ hour}$ for Kassasin loamy sand soil particle size fractions were 41.8, 40.4 and 48.1°C, respectively. Such values decreased to 30.0, 26.3 and 30.8°C at 6 hours, respectively. The initial values obtained for Nubaria calcareous sandy loam soil particle size fractions were 43.8, 52.1 and 52.8°C, respectively. These values decreased at 6 hours to 31.8, 33.3 and 33.6°C. It was interestingly found that Nubaria calcareous sandy loam total heat gained during 6 hours per gram for the 4.175, 2.675 and 1.59 mm in diameter particle size fractions within the upper 20 centimeters are 10.75, 19.08 and 21.35 respectively, Table (4). The corresponding values for Kassasin loamy sand soil particle size fraction are 7.39, 13.43 and 18.23, respectively. This result indicates that Nubaria calcareous sandy loam soil will probably be warmer than Kassasin loamy sand soil during day time. However, under field conditions, it should be expected that the reverse is true due to the high albedo for Nubaria calcareous sandy loam soil. Hence, the values obtained for Nubaria calcareous sandy loam soil total heat gained during 6 hours heating by solar radiation should be less than 10.75, 19.08 and 21.35 calory per gram for the forementioned particle size fractions. On the other hand, total heat loss in calories during 6 hours per gram for the forementioned particle size fractions from the upper 30 cm to the atmosphere from Nubaria calcareous loamy sand are 4.70, 10.43 and 10.87, respectively. The corresponding values for Kassasin loamy sand soil particle size fractions are 5.49, 6.38 and 9.03 respectively. Therefore, it is anticipated that the Nubaria sandy loam soil will be cooler than the Kassasin loamy sand soil. It should be pointed out that Nubaria calcareous sandy loam particle size fractions had lower apparent densities and higher $CaCO_3$ contents than the Kassasin soil particle size fractions.

Table (4): Soil temperature profiles during heating and cooling cycles for
A) Kassasin loamy sand soil particle size fractions

Depth cm	Heat gain									Heat loss									
	T_0 °C →	$T_{1.5\,hr.}$	Cal. period/g	$T_{3\,hr.}$	Cal. period/g	$T_{4.5\,hr.}$	Cal. period/g	$T_{6.0\,hr.}$	Cal. perio./g	T_0 °C →	$T_{1.5}$ hr.	Cal. period/g	$T_{3\,hr.}$	Cal. period/g	$T_{4.5}$ hr.	Cal. period/g	$T_{6.0}$ hr.	Cal. period/g
4.175 mm diameter																			
0.0	25.9	40.4	—	51.6	—	55.9	—	60.0	—	59.6	41.7	—	35.0	—	32.8	—	30.9	—
2.5	26.1	35.9	+3487.78	41.7	+2440.01	45.5	+1162.59	50.6	+1320.48	58.2	41.7	-4937.43	36.2	-1751.07	34.1	-617.18	32.1	-559.77
5.0	26.2	28.0	+1664.95	31.9	+1392.24	34.9	+976.00	36.9	+1019.06	50.1	38.4	-4047.55	35.6	-1191.30	33.9	-545.41	32.5	-488.00
10.0	26.2	26.4	+574.12	26.4	+1119.53	26.4	+861.18	26.5	+602.63	29.0	29.2	-3301.19	29.7	-660.24	29.8	-459.30	29.6	-459.30
20.0	26.2	26.4	+229.65	26.4	+0000.00	26.4	+0000.00	26.5	+114.82	28.0	27.0	-574.12	27.2	+401.88	27.3	+114.82	27.3	-114.82
30.0	—	—	—	—	—	—	—	—	—	25.9	27.0	-57.44	27.2	+229.65	27.3	+114.82	27.3	000.00
Total	—	—	5956.50	—	4951.78	—	2999.77	—	3056.99	—	—	12917.70	—	2971.08	—	1392.25	—	1621.82
	grand total heat gain = 16965.04 mass soil in 20 cm depth = 2296.48g ∴Total heat gain, Cal. 6hr./g=7.3874									grand total heat loss = 18902.92 mass soil in 30 cm depth = 3444.72g ∴ Total heat loss, Cal 6hr./g= 5.4875									
2.675 mm diameter																			
0.0	20.5	56.4	—	68.1	—	73.6	—	75.9	—	74.6	53.7	—	41.0	—	37.0	—	34.2	—
2.5	20.5	23.8	+5695.96	35.3	+3371.08	47.1	+2513.78	56.1	+1278.68	56.4	47.5	-4330.09	33.8	-3836.05	30.0	-1133.38	27.1	-828.24
5.0	20.5	21.6	+639.34	26.0	+2310.35	33.3	+2775.33	39.1	+2223.17	41.2	38.2	-1729.13	33.0	-2746.26	29.1	-1118.85	26.6	-784.65
10.0	20.5	20.3	+261.55	20.7	+1394.93	23.3	+2877.04	26.3	+2702.67	28.7	29.9	+523.10	29.7	-1569.29	28.5	-1482.11	26.0	-1453.05
20.0	20.5	20.3	000.00	20.7	000.00	21.3	+1859.90	20.6	+12336.81	20.6	20.7	+755.59	21.2	+174.37	22.2	-1278.68	22.4	-1336.81
30.0	—	—	—	—	—	—	—	—	—	20.6	20.7	000.00	21.2	+290.61	21.0	-697.46	21.4	+348.73
Total	—	—	6596.85	—	7076.36	—	10002.05	—	7541.33	—	—	-4780.53	—	-7686.62	—	-5710.47	—	4054.02
	grand total heat gain = 31216.59, mass soil in 20 cm depth =2324.88 g ∴Total heat gain, Cal. 6hr./g=13.4272									grand total heat loss = 22231.65, mass soil 30 cm depth = 3487.32 g ∴Total heat loss, Cal. 6hr./g=6.3750									
1.59 mm diameter																			
0.0	25.2	57.5	—	68.9	—	74.3	—	76.7	-	74.9	52.5	—	43.5	—	38.1	—	33.3	—
2.5	25.2	33.6	+6058.20	47.1	+3706.37	56.4	+2188.10	62.8	+1309.88	63.6	46.6	5909.35	42.9	-1845.74	37.8	-1562.93	32.8	-1458.73
5.0	25.2	29.9	+1949.94	40.4	+3572.40	49.1	+2679.30	54.6	+1771.32	56.4	47.8	-3810.56	42.0	-1414.08	37.6	-1414.08	32.5	-1503.39
10.0	25.2	25.7	+1548.04	28.4	+3929.64	33.7	+4048.72	37.4	+2738.84	40.0	40.7	-2351.83	39.9	-1964.82	37.1	-2143.44	31.7	-3125.85
20.0	25.2	25.7	+595.4	25.9	+1726.66	26.1	+3274.7	26.3	+2322.06	27.1	28.7	+1369.42	29.6	+59.54	29.3	-1845.74	28.3	-3810.56
30.0	—	—	—	—	—	—	—	—	—	26.5	26.8	+1131.26	27.8	+1131.26	28.0	-59.54	26.1	-1726.66
Total	—	—	10151.58	—	12935.07	—	12190.82	—	8142.10	—	—	-9571.06	—	-4033.84	—	-7025.73	—	-11625.19
	grand total heat gain = 43419.59 , mass soil in 20 cm depth = 2381.6g ∴Total heat gain, Cal. 6hr./g= 18.2313									grand total heat loss = 32255.82, mass soil in 30 cm depth = 3572.49 g ∴Total heat loss, Cal. 6hr./g= 9.0292									

Table (4): Cont.

B) Nubaria calcareous sandy loam soil particle size fractions.

	Heat gain									Heat loss								
Depth cm	T_0 °C →	$T_{1.5 hr.}$	Cal. period/g	$T_{3 hr.}$	Cal. period/g	$T_{4.5 hr.}$	Cal. period/g	$T_{6.0 hr.}$	Cal. period/g	T_0 °C →	$T_{1.5 hr.}$	Cal. period/g	$T_{3 hr.}$	Cal. period/g	$T_{4.5 hr.}$	Cal. period/g	$T_{6.0 hr.}$	Cal. period/g
4.175 mm diameter																		
0.0	27.2	53.3	—	63.1	—	67.6	—	69.7	—	69.1	53.4	—	42.3	—	37.8	—	35.0	—
2.5	27.2	45.5	+5546.67	53.5	+2223.67	56.7	+961.92	58.4	+474.72	58.7	50.0	-3048.17	42.3	-2348.59	37.0	-1224.27	33.9	-737.06
5.0	27.2	32.0	+2885.77	38.3	+1786.43	41.7	+824.51	43.5	+437.24	45.5	44.8	-1174.30	41.5	-549.67	36.4	-1299.22	33.6	-737.06
10.0	27.2	28.0	+1399.16	28.6	+1739.97	28.9	+924.45	29.0	+474.72	31.2	31.8	-241.99	31.8	-824.51	32.1	-1199.28	31.4	-524.69
20.0	27.2	28.0	+799.52	28.6	+599.64	28.7	+199.88	29.0	+199.88	29.1	29.4	+449.73	29.2	-99.94	29.1	+99.94	28.3	-49.97
30.0	—	—	—	—	—	—	—	—	—	29.1	29.4	+299.82	29.2	-199.88	29.1	-99.94	28.3	-799.52
Total	—	—	10631.12	—	6349.71	—	2910.76	—	1586.56	—	—	-3497.91	—	-4022.59	—	-3722.75	—	-2848.30
	grand total heat gain = 21478.15, mass soil in 20 cm depth = 1998.8 g ∴Total heat gain, Cal. 6hr./g=10.7455									grand total heat loss = 14091.55, mass soil in 30 cm depth = 2998.29 g ∴ Total heat loss, Cal 6hr./g= 4.7000								
2.675 mm diameter																		
0.0	28.6	56.1	—	68.3	—	72.9	—	75.6	—	74.5	50.2	—	41.6	—	38.0	—	35.8	—
2.5	28.6	55.5	+6940.62	67.2	+3049.28	72.3	+1237.57	75.1	+701.72	74.1	48.4	-6379.25	40.5	-2105.15	37.6	-829.30	35.0	-612.41
5.0	28.6	41.2	+5039.61	50.6	+2692.04	54.6	+1161.02	57.2	+688.96	59.2	48.2	-4682.37	40.4	-2003.08	36.3	-893.10	33.8	-650.68
10.0	28.6	30.1	+3597.90	34.6	+3546.86	39.2	+2194.46	42.1	+1403.44	45.0	43.6	-3164.11	39.8	-2959.97	35.8	-2066.88	33.4	-1250.33
20.0	28.6	28.5	+714.48	27.8	+1939.29	27.9	+2398.60	28.2	+1633.09	30.8	31.6	-306.20	32.0	-1735.16	32.3	-1888.26	32.0	-1377.92
30.0	—	—	—	—	—	—	—	—	—	28.9	29.1	+510.34	29.5	+408.27	29.5	+153.10	29.6	-102.07
Total	—	—	16292.61	—	11227.47	—	6991.65	—	4427.21	—	—	-14021.59	—	-8395.09	—	-5524.44	—	-3993.41
	grand total heat gain = 38938.94, mass soil in 20 cm depth = 2041.36g ∴Total heat gain, Cal. 6hr./g=19.0750									grand total heat gain = 31934.53, mass soil in 30 cm depth = 3062.04 g ∴Total heat loss, Cal. 6hr./g=10.4292								
1.59 mm diameter																		
0.0	25.5	57.9	—	68.7	—	73.4	—	76.3	—	74.9	53.8	—	42.3	—	38.2	—	35.7	—
2.5	25.5	46.5	+7096.86	59.3	+3136.44	64.6	+1329.00	70.3	+1142.94	74.6	53.7	-5581.80	41.6	-3136.44	37.8	-1049.91	34.9	-717.66
5.0	25.5	37.7	+4412.28	49.9	+3322.50	54.0	+1249.26	57.7	+1249.26	61.8	52.0	-4080.03	41.2	-3043.41	37.2	-1036.62	34.3	-770.82
10.0	25.5	28.3	+3987.00	34.4	+4864.14	39.0	+2312.46	41.6	+1674.54	46.3	45.7	-2764.32	41.0	-4119.91	37.0	-2126.40	34.2	-1515.06
20.0	25.5	28.3	+2976.96	27.2	+2658.00	27.6	+2658.00	27.5	+1329.00	30.6	31.4	-106.32	32.5	-1913.76	33.1	-2445.36	32.5	-1807.44
30.0	—	—	—	—	—	—	—	—	—	28.8	29.4	+744.24	29.9	+850.56	30.3	-106.32	30.2	-372.12
Total	—	—	18473.10	—	13981.08	—	7548.72	—	5395.74	—	—	-11575.59	—	-11362.96	—	-6551.97	—	-5183.10
	grand total heat gain = 45398.64, mass soil in 20 cm depth = 2126.4g ∴Total heat gain, Cal. 6hr./g=21.3500									grand total heat loss = 34673.62, mass soil in 30 cm depth = 3189.6 g ∴Total heat loss, Cal. 6hr./g=10.8708								

Table (5): Total and partial heat gain from disc heater within the upper 20 cm or loss to the atmosphere from the upper 30 cm for the investigated soils particle size fractions.

Heat gain, cal. period/g					Kassasin loamy sand soil	Heat loss, cal. period/g				
1.5 hrs	1.5-3.0 hrs	3.0-4.5 hrs	4.5-6.0 hrs	Total heat/ 6.0 hrs	Particle size fractions (mm in diameter)	1.5 hrs	1.5-3.0 hrs	3.0-4.5 hrs	4.5-6.0 hrs	Total heat/ 6.0 hrs
2.5939	2.1562	1.3062	1.3311	7.3873	4.175	3.7500	0.8625	0.4042	0.4708	5.4875
2.8375	3.0436	4.3022	3.2438	13.4273	2.675	1.3708	2.2042	1.6375	1.1625	6.3750
4.2625	5.4313	5.1188	3.4188	18.2314	1.590	2.6792	1.1292	1.9667	3.2542	9.0293
					Nubaria calcareous sandy loam soil particle size fractions					
5.3188	3.1768	1.4563	0.7938	10.7457	4.175	1.1667	1.3417	1.2417	0.9500	4.7001
7.9813	5.5000	3.4250	2.1688	19.0751	2.675	4.5792	2.7417	1.8042	1.3042	10.4293
8.6875	6.5750	3.5500	2.5375	21.3500	1.590	3.6292	3.5625	2.0542	1.6250	10.8709

Partial heat gain or loss occurred during the first 1.5 hours generally exhibited the highest values and gradually decreased with the progress in time, Table (5). In this respect, De Vries (1963) Ghuman and Lal (1981 and 1982); Evenori, *et al.* (1982) and Semmel *et al.* (1990) stated that the magnitude of soil heat storage or release can be significant over a few hours, but is usually small from day to day. It was also interestingly noticed for both soil particle size fractions that partial or total heat gain or loss generally increased as particles diameter decreased. Ghuman and Lal, (1985) stated that clay soil have low thermal conductivity due to its low bulk density and this suggests that they would exhibit larger surface temperature amplitudes compared with loamy or sandy loam soils under equal heat flux densities.

4. REFERENCES

Black C.A. (1965). Soil-Plant Relationships. 2nd, edition, John Wiley Sons, Inc. New York. London 1976.

Campbell G.S. (1985). Soil Physics with Basic Transport Models for Soil-Plant Systems. Elsevier, Amsterdam.

Cary J.W. and Taylor S.A. (1962). The interactions of the simultaneous diffusions of heat and water vapor. Soil Sci. Soc. Amer, Proc. 26: 314-416.

Cassel D.K., Nielson D.R. and Bigger, J.W. (1969). "Soil water movement in response to imposed thermal gradients". Soil Sci. Soc. Amer. Proc. 34: 183-189.

De Vries D.A. (1963). Thermal properties of soils. In Van Wijk, W.R. (Ed.), Physics of Plant Environment. North Holland Publishing. Amsterdam, pp 210-235.

Eigenson L.S. (1952). Simulation (Modelirorni) soviet science, Moscow.

Evenari M.,Shanan L. and Tadmor M. (1982). The challenge of a Desert, 2nd, ed. Harvard University Press, Cambridge MA.

Gee G.W. and Bauder J.W. (1986). Particle size analysis. In Methods of Soil Analysis, Part 2 (Ed-Klute)p.p. 383-411 (ASA and SSSA: Madison, Wis.).

Geiger R.(1965). The Climate Near the Ground. Cambridge, Mass.: Harvard University Press.

Ghuman B.S. and Lal R. (1981). Predicting diurnal temperature regime in a tropical soil. Soil Sci. 132: 247-252.

Ghuman B.S. and Lal R. (1985). Thermal conductivity, thermal diffusivity, and thermal capacity of some Nigerian soils. Soil Science 139, 74-80.

Golovanov A.I. (1969). Measuring thermal conductivity of soils under laboratory conditions Neth. J. Agric. Sci., 17: 71-79.

Hadas A. (1977_a). Evaluation of theoretically predicted thermal conductivities of soils under field and laboratory conditions. Soil Sci. Soci. of Amer. Jour. 41, 460-466.

Hadas A. (1977_b). Heat transfer in dry aggregated soil. 1. Heat Conduction. Soil Science Society of America Journal 41, 1055-1059.

Johnson M.D. and Lowery B. (1985). Effect of three conservation tillage practices on soil temperature and thermal properties. Soil Sci. Soci. Amer. Jour. 49, 1547-1552.

Jury W.A., Gardner W.R. and Gardner W.H. (1991). Soil Physics, 5th ed. Wiley, New York.

Klute A. (Ed.) (1986). Methods of Soil Analysis, part 1: Physical and Mineralogical methods, (2nd, Ed.). Agron. 42: 95-109. Academic Press, Inc., USA.

Nimmoc J.R. and Kstin K.C. (1988). Hydraulic conductivity of a sandy soil at low water content after compaction by various methods. Soil Sci. Soc. Amer. Jour., 52: 303-310.

Page A.L. (Ed.) (1982). Methods of Soil Analysis part 2: Chemical and Microbiological Properties (2nd Ed.) Agron. J. 9: A.S.A., Inc., Madison, Wis., USA.

Parlange M.B., Cahill A.T., Nielsen, D.R., Hopmans, J.W. and Wendroth, O. (1998). Review of heat and water movement in field soils. Soil Tilage Research. 47, 5-10.

Semmel H., Horn R., Hell U., Dexter A.R. and Schulze E.D. (1990). The dynamics of soil aggregate formation and the effect on soil physical properties. Soil Technology. 3, 113-129.

Van Wijk W.K.(ed). (1963). Physics of plant environment, New York: Wiley.

مشاركة المجاميع الحجمية لحبيبات الأرض فى حرارة قطاعاتها وخصائصها الحرارية

محمد هانى احمد غالى ، سمير على محمد*

قسم الأراضى ، معهد الكفاية الإنتاجية، جامعة الزقازيق
*قسم الأراضى والمياه ، كلية زراعة الإسماعيلية، جامعة قناة السويس

ملخص

أجريت تجربة معملية فى أعمدة أسطوانية مزودة بأجهزة لقياس حرارة أعمدة تربه ومفصولات المجاميع الحجمية لحبيبات نوعين من التربة خلال عمليات الاكتساب والفقد الحرارى. وقد تم فصل ثلاثة مجاميع حجمية للحبيبات من تربة القصاصين الطميية الرملية ومن تربة النوبارية الجيرية الرملية الطميية ورصدت درجات الحرارة على طول المحور الراسى بمركز عمود التربة باستخدام سلك المزدوج الحرارى، نحاس – كونستانتان ومقياس رقمى للحرارة. حسبت السعات الحرارية والحرارة الكلية المكتسبة والمفقودة وأجزائها للمجاميع الحجمية للتربتين ودرس تأثير المجاميع الحجمية للحبيبات ومساميتها على سريان الحرارة.

وجد أن التباين الحرارى مع العمق لتربة القصاصين الطميية الرملية اقل منه لتربة النوبارية الجيرية الرملية الطميية ووجد أيضا اعتماد السريان الحرارى على طول عمود التربة على الكثافة الظاهرية والمجاميع الحجمية للحبيبات يرجع الى الاختلاف فى التوصيل الحرارى.

كانت الحرارة الكلية المكتسبة أثناء ٦ ساعات تسخين خلال الـ ٢٠ سم العليا لعمود التربة للمجاميع الحجمية المختلفة للحبيبات تربة النوبارية الجيرية الرملية الطميية التى لها متوسطات أقطار (٤,١٧٥ ، ٢,٦٧٥ وأيضا ١,٥٩ مم) وكذلك الحرارة الكلية المفقودة للجو خلال الـ ٣٠سم العلوية أعلا من نظائرهم المتحصل عليهم لتربه القصاصين الطميية الرملية وهذه الاستجابة ترجع لانخفاض الكثافات الظاهرية وارتفاع محتويات كربونات الكالسيوم لارض النوبارية.

دونت أجزاء الحرارة المكتسبة أو المفقودة أثناء الساعة ونصف الأولى من التسخين او التبريد أعلى القيم التى نقصت بزيادة الزمن وقد زادت عموما قيم الحرارة الكلية وأجزائها المكتسبة أو المفقودة لكل من مجاميع الأجزاء الحجمية للحبيبات لكلا النوعين من التربة بنقص أقطار الحبيبات لمجاميع الأجزاء الحجمية.

المجلة العلمية لكلية الزراعة – جامعة القاهرة – المجلد (٥٣) العدد الرابع
(أكتوبر ٢٠٠٢):٦٧١-٦٨٨.