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THE STUDY OF SOIL HEAT TRANSFER CHARACTERISTICS FOR DEVELOPMENT OF COST-SAVING AIR CONDITIONING SYSTEM USING EARTH COOL DEHUMIDIFICATION METHOD

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Abstract
This is a study of soil heat transfer characteristic at equator zone within latitudes ½ ° and 7 ° N and longitudes 100 ° to 1191/2 ° E in Peninsular of Malaysia. Soil heat transfer parameters selected were thermal resistance, thermal conductivity and delta heat. Soil Canter Lab (Malaysia) uses the Proctor Test to find the maximum moisture content and optimum dry density for six samples of soil which were then used in experiment onto samples. The Dry Oven Method was used to find moisture content, Sand-Cone Method was used to find the dry density and Thermocouple was used to find the heat of soil at 100mm and 150mm depths every one minute in thirty minutes. Kersten's Method was used to calculate thermal conductivity of soil and Fourier's Law was used to calculate heat transfer for each sample of soil. Sandy type soil has a higher thermal conductivity, delta heat and soil heat transfer than the salty clay type of soil. Peninsular Malaysia was influenced by Tropical Rainforest climate. It is warm and humid for the whole year round. Higher mean annual rainfall at approximately 2300mm per annum gives advantages to develop an underground air conditioning system according to higher heat transfer of soil and for cost saving but more importantly, it is an environmentally clean system.

Keywords:Soil heat transfer, Thermal conductivity, Delta heat, Moisture content and dry density

1. Introduction

Soil heat transfer can be derived by soil heat flux. Soil heat flux, G (Km^{-1}) is conduction energy per unit area in respond to the temperature gradient.

$$G = -\lambda\ \delta T/\delta z \qquad (1)$$

Where $\lambda (W\ m^{-1}\ K^{-1})$ is thermal conductivity and $\delta T/\delta z\ (^oCm^{-1})$ is temperature gradient. Temperature gradient is positive when temperature decreases toward of depth in soil. Soil rate heat transfer is given by:

$$G=Q/(A\ .\ t) = [C_v\ .\ V\ .\ (T_f\text{-}T_i)]\ /\ (A\ .\ t) \qquad (2)$$

Where C_v *is* $(Jm^{-3}\ K^{-1})$ is heat capacity of soil, $t(s)$ is the time, $V(m^3)$ is the volume of soil, $A(m^2)$ is the area of soil and $\Delta T(K)$ is the heat. This formula obeys Fourier law in non-steady state heat flux condition.

Soil is natural medium made up of mineral particles; clay, silt and sand, organic matter; decaying plant and animal material, water, air and living or organism (soil biota); ranging, fungi and earth warm. Soil characteristic include moisture content, dry density, structure and texture. Soil characters play importance roll in soil thermal conductivity which is dirt proportional with soil heat transfer of soil. Thermal conductivity described as the quantity of heat that flows through a unit area in a unit time under a unit temperature gradient. The experiment to find thermal conductivity of soil was published by Kersten (1949), De Vries(1963), Kimbal *et al*(1976), Sikora and Kossowski (1993), and Ochsner *et al*(2001). Formula to found thermal conductivity of soil by Kersten(1949) is used in this investigation. Thermal conductivity influenced by two factors, they are moisture content and dry density (Van Rooyen and Winterkorn,1957), Johansen (1975), De Vries (1952), Gemant (1952), and Kersten (1949). The decrease of effective thermal conductivity with a decrease in grain size may be explained by the fact that as the grain size decreases, more particles are having the same porosity, which means more thermal resistance between particles. The effect of water content on soil thermal conductivity has received more attention than the effects of other physical characteristics by Smith(1960), Al Nakshabandi and Kohnke(1965), Fritton et al (1974), Parikh et al.(1979), Riha et al.(1980).

According moisture content is important role in underground air conditioning system and bad effect from pollution of air by usual air conditioning also advantages from tropical rain forest it is worm and wet whole years soil heat transfer characteristic will be researching. There for, the objective of the project is firstly to study of soil heat transfer characteristic for six sample of soil. Second, to finding the soil moisture content, dry density and delta heat using experiment and next to finding thermal conduction, thermal resistance using both of the data and finally to finding rate of soil heat transfer for each sample of soil.

2. Methodology

Investigation on soil heat transfer was involves the following steps:

i. Design and fabricate the cylinder pipe, tank and water channel.
ii. Sieve Test and Proctor Test
iii. Density Test, Moisture Test and Heat Test.
iv. Calculate to using Fourier's formula and Kersten's formula.

2.1 Design and fabricate the cylinder pipe, tank and water channel.

Design the cylinder pipe, tank and water channel using 2D and 3D software. To run the experiment, box will be fabricate using mild steel with 60cm long, 60cm thickness and 40cm wide. Cylinder pipe will be test from leakage first before being used to experiment. Leakage from pipe would effect on temperature of soil and material itself. This temperature would give incorrect data to calculate heat transfer rate of soil. Hot water is put into the cylinder pipe. After 10 minute, check the joint cylinder pipe. If there is any leakage put some paste glue to stop the water come out from that joint pipe.

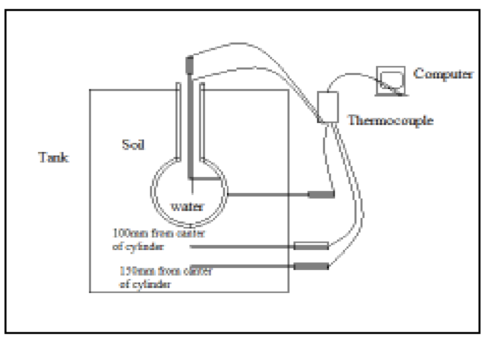

Figure 1: Drawing the experiment of soil heat ransfer

The section of high probability leakage

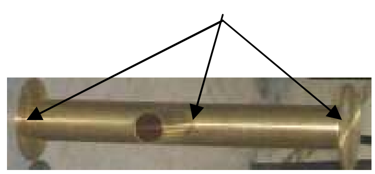

Figure 2: Leakage test for cylinder pipe

2.2 Sieve Test and Proctor Test

Sieve test was done to investigate the size and the classification six type of soil witch that will be test in finding soil heat transfer. Each soil have different structure, size, organic, density and moisture contain. Six type of soil are Peat soil, Loam soil, Organic soil, Coarse Sand, Fine sand and Fine coarse gravel. All of the soils were taken at Malaysia. Standard Proctor Compact test ASTM D1557-91 was used to find optimum moisture content and maximum dry density of each six samples of soil.

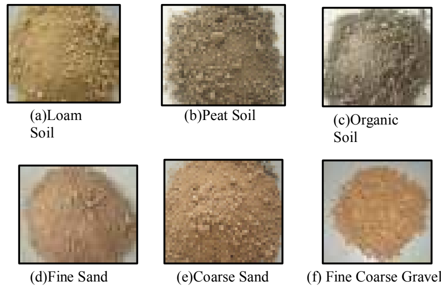

Figure 3: Sample of soil

2.3 *Density Test*

Density and moisture are important factor that is influence the soil heat transfer. Sand Cone Test (ASTM D1556-90) is used to determine the density of soil in tank. Particle density (*Ps*) is the mass of the dry soil contained in unit volume of material. Bulk density (*Pd*) is the mass of material (including solid particles and any contained water) per unit volume including voids. Equation 3, bellow is to faindng density particles of soil.

$$P = m_s / v_s \,. \qquad (3)$$

Were m_s is the mass soil specimen in g and v_s is volume of soil in m^3. After that, calculate the dry density of the soil using formula:

$$Pd = 100Ps / (100 + w). \qquad (4)$$

Were P is bulk density of specimen (Mg/m^3) and w is water content.

2.4 *Moisture Test*

Moisture content (w) the mass of water which can be remove from the soil, usually by heating at 105 °C, expressed as a percentage of the dry mass. The term water content is also widely used. Calculate the moisture content of the soil specimen, w, as a percentage of the dry soil mass to the nearest 0.1 %, from the equation:

$$w = (w2 - w3) / (w3 - w1) \times 100\% \qquad (5)$$

Where, $w1$ is the mass of container (g), $w2$ is the mass of container and wet soil (g) and $w3$ is the mass of container and dry soil (g),

2.5 *Heat Test*

Firstly put the cylinder pipe into the tank. The depth of cylinder pipe in the tank is 150mm below the surface. Two screws are used to hold the cylinder from falling to ground of the tank. After that, fill up the soil into that tank. To compact the soil, compact tool is used. Next, boil the water approximate to 100^0C, put this hot water in the cylinder. Then, close the cylinder with cover and take the reading of temperature in every one minute till 30 minutes using thermocouple.

2.6 *Thermal Conductivity, Delta Heat and Heat Transfer Calculation*

The soil thermal conductivity is found using the equation (6) for unfrozen silt and clay type of soil and (7) for unfrozen sandy types of soil.

$$K = [0.13 \log w - 0.0288]10^{0.000624 p_s}] \,. \qquad (6)$$

$$K = [0.101 \log w + 0.0577]10^{0.000624 p_s}] \qquad (7)$$

in *W/(m·K)* unit were; *w* denotes soil moisture*(%)* and *Ps* is density of soil, *kg/m3*. Fourier formula was used to find the heat transfer of soil.

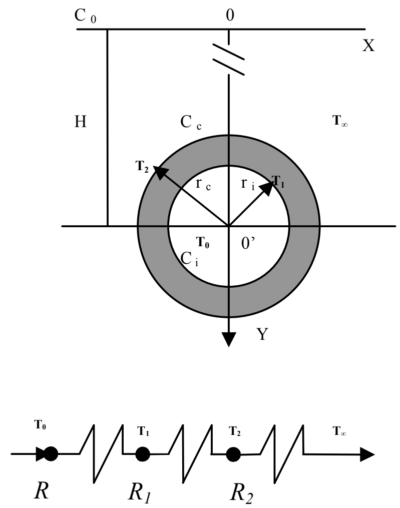

Figure 4: Illustrate of cylinder pipe on underground

$Q_{\ heat\ transfre} = (T_0 - T\infty) \ / R_{\ total}$ (8)

Were, Q is heat transfer of soil, ΔT is difference of temperature and total resistance equation is:

$R_{total} = R_0 + R_1 + R_2$. (9)

$R_0 = 1 / hxA$(convection in hot water) (10)

$R_1 = 1n(r\ 2 /r\ 1) / K_1\, xA_{\ 1}$(conduction in material pipe) (11)

$R_2 = 1n(r\ 3 /r\ 2) / K_2\, xA_{\ 2}$(conduction in soil) (12)

Were, h is heat transfer coefficient, A is area of the hot water in cylinder pipe, $r_{\ 1}$ is radius inter hollow cylinder, r_2 is radius outer hollow cylinder, K_1 is thermal conductivity of the cylinder pipe, A_1 is area of the cylinder pipe, r_3 is radius of inter soil, r_4 is radius outer hollow cylinder, K_2 @ λ_s is thermal conductivity of soil and A_2 is area of soil along the pipe.

3. Result and Discussion

The proctor tests were done for the six types of soil to find the Thermal Conductivity at Optimum moisture Content and Maximum Dry Density. The experiments were done for this type of soil to find the Soil Heat Transfer. The result maximum moisture content, optimum dry density, thermal conductivity, thermal resistance and heat transfer of soil were shown in the table 1 and table 2 below.

3.1 Soil Moisture Content.

The result from experiment in table 1, show that Soil moisture content increases, hence the thermal conductivity increasing too. Initial hypothesis found that moisture action as a field's connection molecules of soil to transfer of heat. Low moisture content, hence heat to transfer to underground of soil is week. Too much of moisture content, hence the heat almost to transfer by water not particles of soil. Thermal conductivity of peat soil is 0.7527 W/(m.k) at 45.11% Moisture content but 0.5224W/(m.k) at 4.7% for coarse sand.

Table 1: Result of moisture content, bulk density and thermal conductivity from Proctor Test and Experiment.

Samples of Soil	Descriptions of soil	Moisture Content		Bulk Density		Thermal Conductivity	
		W_e	W_t	P_e	P_t	K_e	K_t

		%	%	(Mg /m^3)	(Mg / m^3)	W / (m.K)	W / (m.K)
Peat Soil	**Dark grayish clay silt with traces and root**	45.11	27.8	0.972	1.33	0.7527	1.0743
Coarse Sand	**Coarse sand (Brownish)**	4.7	4.52	0.992	1.817	0.5224	1.686
Loam Soil	**Brownish salty clay with soft literate**	34.39	16.4	0.955	1.74	0.6741	1.5732
Fine Coarse Gravel	**Light yellowish brown salty clay witch fine coarse gravels**	21.11	21.6	0.8917	1.65	0.5157	1.5488
Organic Soil	**Light grayish salty clay with some trace**	45.04	25.8	0.972	1.35	0.7513	1.0763
Fine Sand	**Fine Sand (Brownish)**	9.57	6.5	1.009	1.746	0.6683	1.72

Table 2: Result of Heat transfer

Sample of Soil	**Thermal Resistance, R (mK/W)**		**Delta Heat, ΔT/Δt (°K/minute)**		**Heat Transfer, Q(W)**	
	100mm	**150mm**	**100mm**	**150mm**	**100mm**	**150mm**
Peat Soil	15.91	16.01	2.77	0.35	0.17	0.02
Organic Soil	15.74	16.02	2.39	0.54	0.15	0.03
loam Soil	15.83	15.90	1.59	0.12	0.1	0.02
Fine Coarse Gravel	15.84	15.91	3.73	0.23	0.24	0.01
Fine Sand	15.76	16.06	4.11	0.56	0.26	0.03
Rough Sand	16.15	16.37	6.89	2.85	0.43	0.17

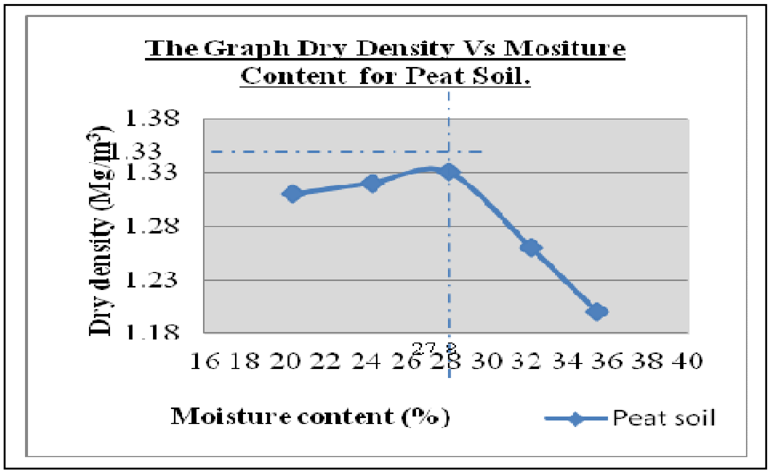

Figure 5: Relationship dry density and moisture content.

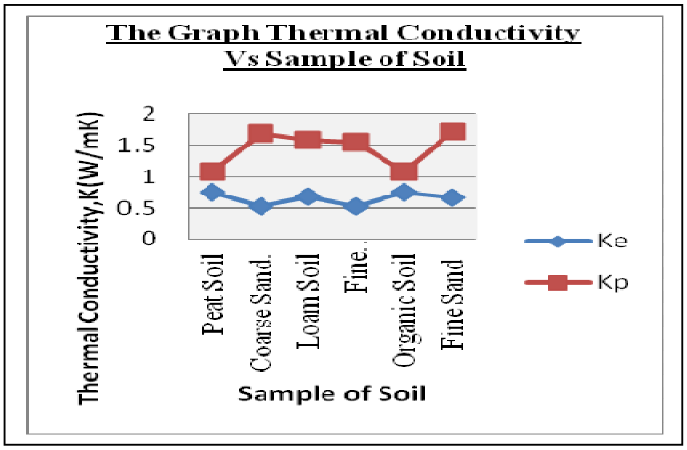

Figure 6: Compeering thermal conductivity by proctor test and experiment.

3.2 Dry density

The result from proctor test show that the higher thermal conductivity is fine sand, it is 1.72W/(mk) and the lowest is peat soil, it is 1.0743W/(mk) even thought the higher moisture content is peat soil, it is 27.8% than fine soil, it is 6.5%. When its compare with amount of dry density , fine sand is 1.746 Mg/m3 but peat soil is 1.33Mg/m3. The hypothesis found that thermal conductivity most influence by dry density. Soil compaction can be defined as the method of mechanically increasing the density of soil. It means of, soil compaction test was used to reduce or to remove the pore surface which is full fill by air and to make the strong bonding between particles of soil. The particles of soil play importance roll to thermal conductivity because the substance contain in particles of soil probability make the higher thermal conductivity of soil. More than that, to increases the resistivity particle of soil. Air void between particles of soil will affect in accurate for the amount of soil heat transfer result. Because the heat will transfer by air but not by soil. It is call heat transfer by radiation from gas not conduction by particle of soil. At the point maximum dry density and optimum moisture content, the gases in void space between particles of soil approximate 100% remove in sample of soil.

3.3 Moisture Content Vs Density

Soil compaction using Proctor test was done on to six sample of soil. The data showed that dry density of soil increasing, when the moisture content increases but when achieve at one point dry density up down even though moisture content was increases. It is happened condition of soil after maximum moisture content at this condition the soil change to saturation condition. The pore space of soil is full fill by liquid and this condition like lubricant between particle produce the bonding between particles of soil is weak. Heat will be transfer in soil 100% by liquid but not particle of soil. There for, heat totally will conduct by liquid. Hence, inaccurate result of thermal conductivity, heat capacity and heat transfer of soil will gate. The trend of graph was same but it was archive the maximum dry density and optimum dry density were differing. It happened because the texture and structure of particle are difference for each sample of soil.

3.4 Texture and structure

Another factor that influences the thermal conductivity of soil is texture of soil. Soil texture is described as a size particle of soil. The bigger the size particle, the lower the bonding between particle of soil and gape between particle contacts each other is quite big. Therefore, void or pore space between particles is large. The samples of soil in research is divided by two type which are coarse sand and fine sand are group of sandy types, organic peat soil, loam soil and fine coarse gravel is mix silt clay and coarse gravel.

3.4.1 Sand type

The size particle of sand type is biggest than silt and the lowest is clay particle. Sandy soil has low water holding capacity and easily damaged. Soil texture is important because it affects, how well it holds water, and how quickly it warms. Sandy soils, allow water to enter and pass through more quickly. Sandy soils warm up more quickly than fine soils and can be tilled more easily; however, they dry out more quickly. Due to biggest size of particle percentage porosity and bulk density is high too. Porosity can be defined by the high amount of pore space or void in soil type.

3.4.2 Mix clay silt and fine coarse gravel

Soil having high porosity and bulk density tend to drain water quicker than low porosity and bulk density (J.Mulqueen, 2005). That is why sandy type has lowest moisture content and high dry density than the silt clay type and direct effect the thermal conductivity of soil. Heavy clay soil is very dense, does not drain water very fast, have small pore surface and can support water very well (H.corole and Ruthergien, 2006). Therefore, pet soil and organic soil contain moisture more than other sample of soil. However this type of soil cannot conduct heat very well because heat which is to be transferred cannot be absorbed quickly to the underground and the heat plays around the cylinder pipe only. So, the heat could not change or recycle very well. Low porosity and bulk density, hence amount of organic matter increases (T.Jamal, 2005).

3.5 Substance particle of soil.

Thermal conductivity decreased with increasing organic matter (peat moss) content. (Nidal, Abu-Hamdeh and Randall, 1999). The result of thermal conductivity of peat soil and organic soil is lower than fine sandy soil, rough sandy soil, loam soil and yellow stone soil.

3.6 *Delta heat of soil*

The amount of delta heat is decreases versus depth; it is showed when compare the data of delta heat at points 100mm and 150mm in depth. The decrease of delta heat is not constant. The influence of delta heat include moisture content, density of soil, texture, arrangement of particle of soil or structure, void space and substance of soil.

3.7 Heat Transfer of Soil

The result of average soil heat transfer at point 100mm and 150 under the soil was showed at table 2 and the graph was showed at figure 7 and 8. Heat transfer of soil shows that the amount is decreases when downward to the underground.

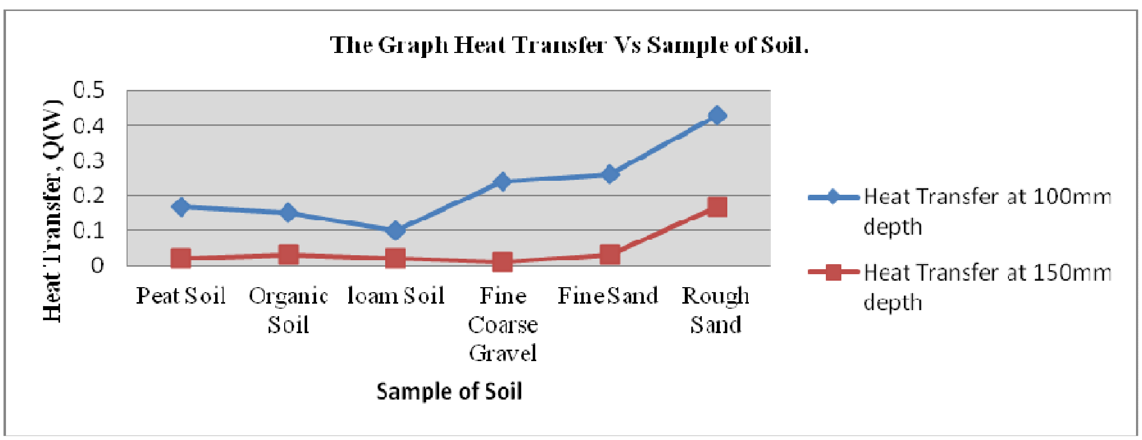

Figure 7: Heat transfer at difference of deepness.

Heat transfer of soil is influenced by two factors, which are delta heat and thermal resistance. This is most influence of thermal conductivity of soil. Thermal conductivity and delta heat of soil is influenced by a few factors. They are moisture content, dry density, texture of soil, structure of soil and porosity. At point 100mm below surface, fine sand has higher heat transfer than coarse sand. However, at point 150mm below surface, coarse sand over take the higher heat transfer than fine sand. Even though thermal conductivity of fine sand is higher and thermal resistance is lower than coarse sand but the delta heat played importance role here. Delta heat at beginning for fine soil is higher but when reaches 150mm the delta heat become lower than coarse sand. Higher delta heat, heat transfer also increases. The trend of loam soil, peat soil, fine coarse gravel and loam soil were affected from delta heat of soil. The cause of this occurrence, were discussed before at delta heat suction.

4. Conclusion

The thermal conductivity for six types of soil via proctor test for peat soil is 1.0743W/(mk).Organic Soil is 1.0763W/(mk), loam soil is 1.5732W/(mK) , fine coarse gravel is 1.5488 W/(mK) , coarse sand is 1.686W/(mK) and fine sand is 1.72W(mK). Thermal conductivity of soil via experiment for peat soil is 0.7527W/(mK), organic soil is 0.7513W/(mK), loam soil is 0.6741W/(mK), fine coarse gravel is 0.5157 W/(mK), coarse sand is 0.5224 W/(mK) and fine soil is 0.6683W/(mK).

Heat transfer for peat soil is 0.17W and 0.02W at 100mm and 150mm in depth. Coarse sand: 0.43W; 0.17W, loam soil: 0.1W; 0.02W, fine coarse gravel : 0.24W; 0.01W, organic soil: 0.15W and 0.03W and fine sand: 0.26W and 0.03W at points 100mm and 150mm.

The study of the soil heat transfer characteristic results has found that soil character were influenced soil heat transfer such as texture, structure, mineral composition and organic contain. They are given direct effect to moisture content in soil and bulk density of soil which is two major component of influences thermal conductivity of soil and delta heat of soil. Thermal conductivity and delta heat is direct proportional to soil heat transfer. Sandy type has characters to absorb heat than other sample.

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