Experimental Investigation On Thermal Conductivity And Electrical Resistivity Of Soil

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Abstract

The thermal conductivity of underground formations is particularly the measurement of their ability to heat transfer. Its determination is critical parameter in the design of several technical projects where heat transfer in soil takes place such as geothermal systems, construction of buried pipes and high voltage cables in the ground. The objective of our research is the investigation (qualitatively and quantitatively) of the influence of the soil physical parameters on thermal conductivity (k) and electrical resistivity (ρ) and the development of an expression that can be used to relate electrical resistivity tomography and geotechnical data to produce soil thermal conductivity profiles. In order to achieve the above mentioned goals, a series of experiments have been performed during which (k) and (ρ) values of five different soil types of known mineralogical composition and grain size distribution were measured while varying moisture and dry density.

Keywords: Thermal Conductivity, Electrical conductivity,physical parameters ,different soil, varying moisture and dry density

I. INTRODUCTION

Soil thermal conductivity (k) is a critical parameter in various engineering applications, where heat transfer takes place and depends on numerous factors such as mineralogical composition, grain size of soil and physical properties (moisture, dry density, saturation). Same factors have also an influence on the electrical resistivity of soil (ρ). This work presents an experimental determination of soil thermal conductivity and electrical resistivity, in various soil types with different grain size and mineral composition, in terms of variable moisture content and dry density. The change of thermal (k) and electrical (inverse of resistivity, ρ) conductivity values in terms of the increasing saturation is interpreted with the increasing presence of water over the air in the pore space that facilitates heat and current transportation. The study of thermal conductivity and electrical resistivity variation according to the fluctuation of physical properties of soils, can lead to the qualitatively and quantitatively correlation between k and ρ. Such an empirical correlation can be used to estimate the thermal conductivity of subsurface, by applying electrical resistivity tomography in combination with geotechnical data. At the present time, it is a subject of further research exploiting various models of k and ρ.

Thermal conductivity and electrical resistivity measurements cover a saturation range between approximately zero value (dry soils) and 92% (almost saturated soils). Greater saturation values could not be achieved under the chosen compaction method. Thermal conductivity increases until a certain value of saturation that differs with the granular range of the sample. The rate of increase is high until saturation values of 20-30% and then it becomes lower up to certain saturation where thermal conductivity values seem to be stabilized. As the grain size decreases, the value of saturation with the highest thermal conductivity increases. This result coincides with other experimental observations (Tarnawski, 2000).

To measure the electrical resistance of the moist insulation material, a simple electrical circuit and an ohmmeter with measuring range to 20000 m ohm are used. The specimen is a cylinder with 25 mm diameter. Two nails are entered into the sides of the moist specimen and ohmmeter electrodes are in contact with these nails. The nails' tip have a distance of 10 mm from each other and just 2 mm of their tips are in contact with specimen and the remained are insulated with a layer of tape. The mass and electrical resistance of saturated specimen which is in contact with ambient is measured in different times.

II.TESTING PROGRAM

2.MATERIALS USED

i) Clay soil
ii) River sand
iii) Red soil
iv)Water
v) Alluvial soil
vi) Black cotton soil

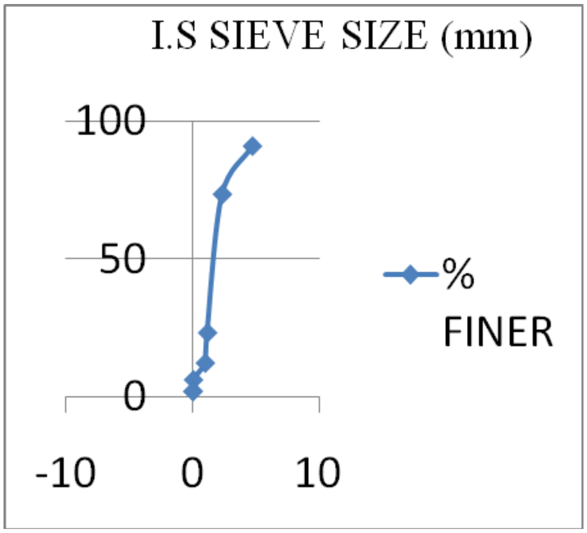
III.EXPERIMENTAL PROGRAM

3.1 SIEVE ANALYSIS

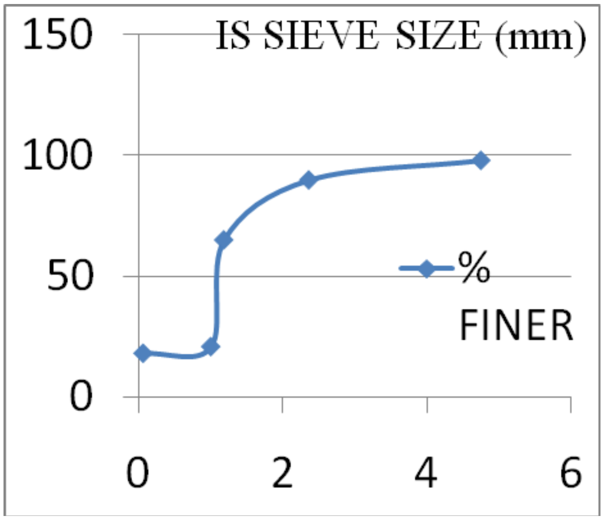
A sieve analysis (or gradation test) is a practice or procedure used to assess the particle size distribution (also called gradation) of a granular material.

The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common

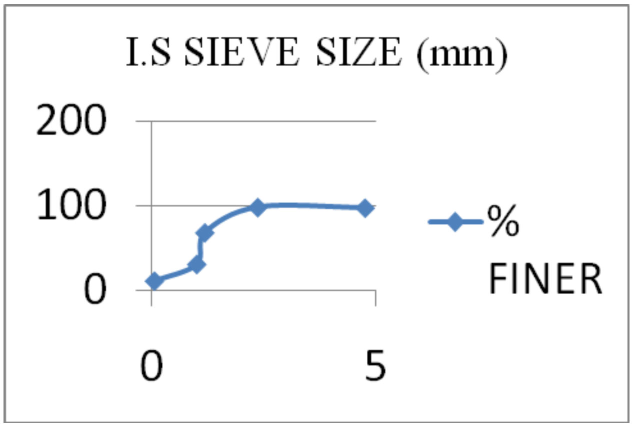
3.1.1. RIVER SAND



3.1.2. BLACK COTTON SOIL



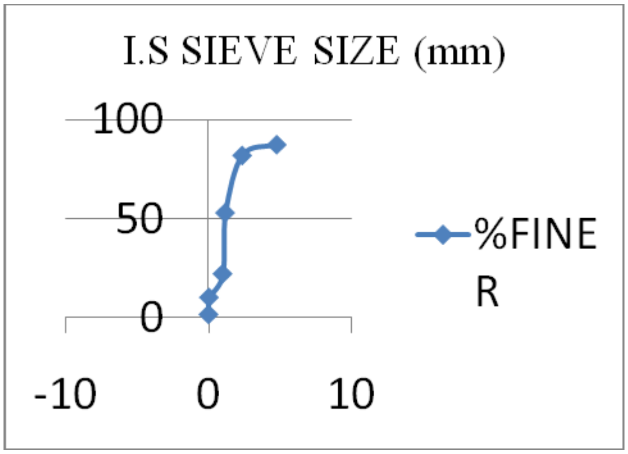
3.1.3. RED SOIL



3.1.4 ALLUVIAL SOIL

S. No	I.S sieve	Retained wt Of soil (gm)	Cumulative wt of soil (gm)	Cumulative % retained (gm)	% finer
1	150 µ	4100	4100	82	18
2	pan	900	5000	100	0

3.1.5. CLAY SOIL



4.1 HYDROMETER ANALYSIS

A hydrometer is an instrument used to measure the particle size of the fine grained soil.

Hydrometer analysis begins after thoroughly mixing the sediment and water, after which particles settle out of the water column according to Stokes's law. The density of a sediment-water suspension depends on the concentration and specific gravity of the sediments present in the mixture. If the suspension is allowed to stand, particles will settle out of the suspension and the density of the sediment-water suspension will decrease. A hydrometer measures the density of the suspension at a known depth below the surface.

We calculate the particle diameter according to the following equation:

$$D = \sqrt{\frac{30\eta}{(G_s-1)}}\sqrt{\frac{L}{t}}$$

Temperature-27 °c
Temperature correction- C_T -7
Viscosity-0.00751(poises)

Fig:4.1 ***HYDROMETER ANALYSIS***

4.1.1 RED SOIL

DIAMETER Vs %FINER FOR RED SOIL

[redacted]

[redacted]

4.1.3 ALLUVIAL SOIL

DIAMETER Vs %FINER FOR ALLUVIAL SOIL

[redacted]

4.1.4. CLAY SOIL

DIAMETER Vs %FINER FOR CLAY SOIL

[redacted]

5

Soil type	Effective size ,D_{10}	Uniform coefficient,$C_u=D_{60}/D_{10}$
Black cotton soil	0.4	6.5
Redsoil	0.23	3.3
Clay soil	0.32	4.1

5.1 PROCTOR'S COMPACTION TEST

5.1 PROCTOR'S COMPACTION TEST

The testing described is generally consistent with the American Society for Testing and Materials (ASTM) standards, and are similar to the American Association of State Highway and Transportation Officials (AASHTO) standards

Diameter of the mould =10.2 cm
Height of the mould =12.2cm
Volume of the mould =9.97x102 cm3
Specific gravity =2.6
Weight of soil taken =3000gm
Weight of the rammer =2.5kg
Number of layers =3
Number of blows =25
Weight of mould =4341gm

TABLE 5.1.1 RED SOIL

s.no	**Water content (m %)**	**Bulk density g/cc**	**Dry density g/cc**	**Saturation g/cc (100%)**
1	6	2.29	2.16	2.25
2	8	2.31	2.13	2.15
3	10	2.32	2.1	2.06
4	12	2.28	2.03	1.98
5	14	2.27	1.99	1.91

TABLE 5.1.2. ALLUVIAL SOIL

s.no	**Water content (m %)**	**Bulk density g/cc**	**Dry density g/cc**	**Saturation g/cc (100%)**
1	6	2.3	1.98	2.20
2	8	2.3	1.74	2.15
3	10	2.31	2.1	2.99
4	12	2.28	2.02	1.98
5	14	2.26	1.98	1.91

Table 5.1.3. BLACK COTTON SOIL

s.no	Water content (m %)	Bulk density g/cc	Dry density g/cc	Saturation g/cc
1	6	2.29	2.16	2.25
2	8	2.3	2.13	2.15
3	10	2.32	2.11	2.06
4	12	2.34	2.08	1.98
5	14	2.36	2.07	1.91

TABLE 5.1.4. CLAY SOIL

s.no	Water content (m %)	Bulk density g/cc	Dry density g/cc	Saturation g/cc (100%)
1	6	2.3	2.16	2.25
2	8	2.32	2.14	2.15
3	10	2.34	2.13	2.06
4	12	2.35	2.09	1.98
5	14	2.36	2.07	1.91

TABLE 5.1.5. RIVER SAND

s.no	Water content (m %)	Bulk density g/cc	Dry density g/cc	Saturation g/cc(100 %)
1	6	2.14	2.01	2.25
2	7	2.09	2.1	2.02
3	8	3	1.98	2.05
4	9	2.41	1.93	2.1
5	10	2.05	1.86	2.06

6.THERMAL CONDUCTIVITY

Thermal conductivity of underground formation is particularly their ability to heat transfer.

In order to achieve the abovementioned goal a series of experiment have been performed during which K and ρ value of different type of soil were measured in moisture and dry density.

$$K= \frac{MS\,(d\theta/dt)\,d\quad(r+2h)}{\Pi r^{2}\;(\theta_1-\theta_2)\quad(2r+2h)}\qquad W/m/K$$

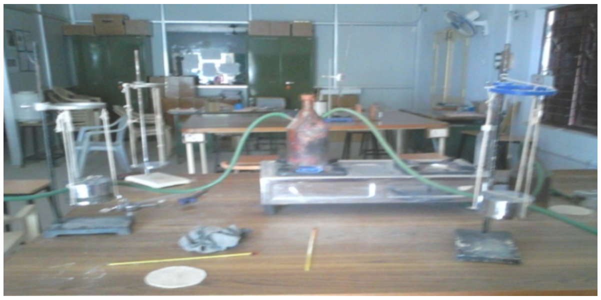


Fig:6.1 THERMAL CONDUCTIVITY BY LEE'S DISC METHOD

FIG 6.1.1 ALLUVIAL SOIL

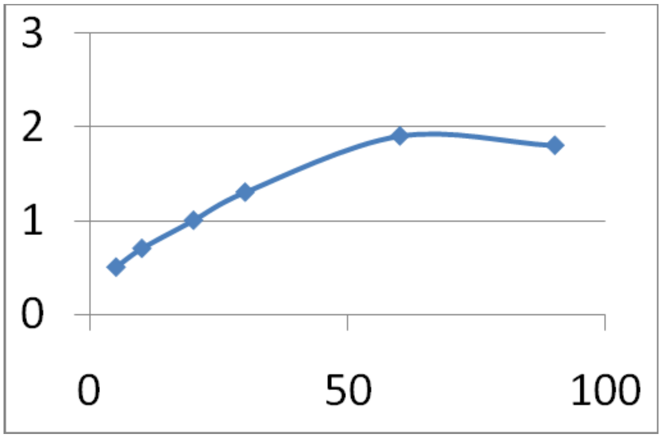


FIG 6.1.2 CLAY SOIL

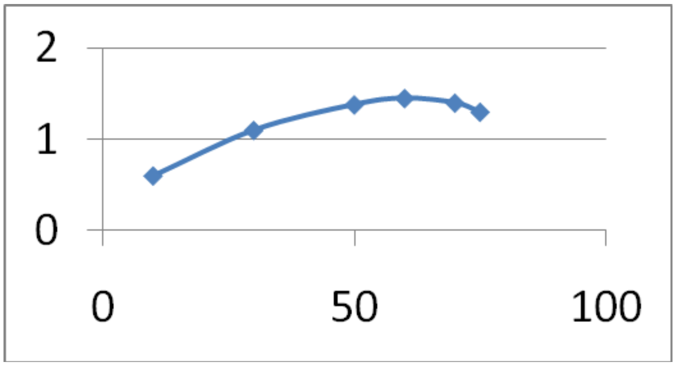


FIG 6.1.3 RED SOIL

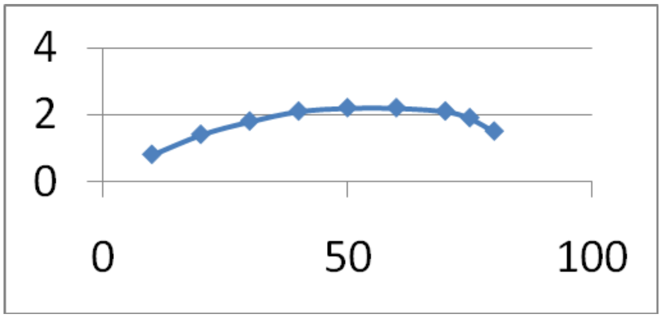


FIG 6.1.4 SAND

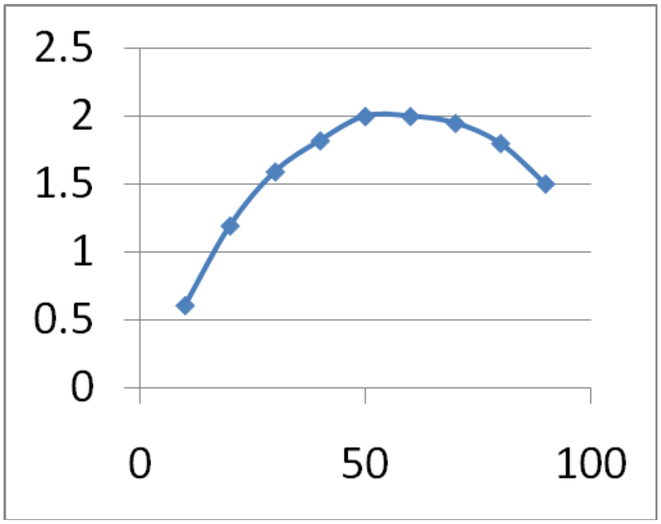
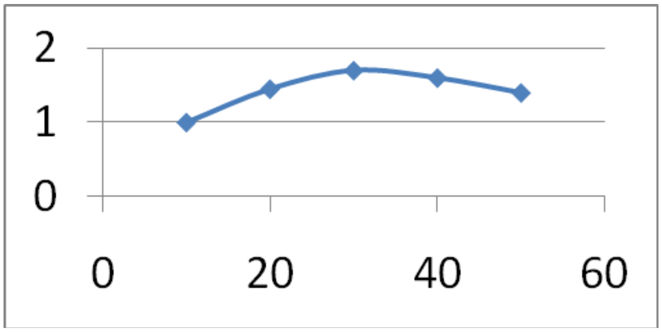


FIG 6.1.5 BLACK COTTON SOIL



7.THERMAL ANALYSIS

The Q600 provides a true simultaneous measurement of weight change (TGA) and true differential heat flow (DSC) on the same sample from ambient to 1,500 °C. It features a field-proven horizontal dual beam design with automatic beam growth compensation, and the ability to analyze two TGA samples simultaneously. DSC heat flow data is dynamically normalized using the instantaneous sample weight at any given temperature

FIG 7.1.1 ALLUVIAL SOIL

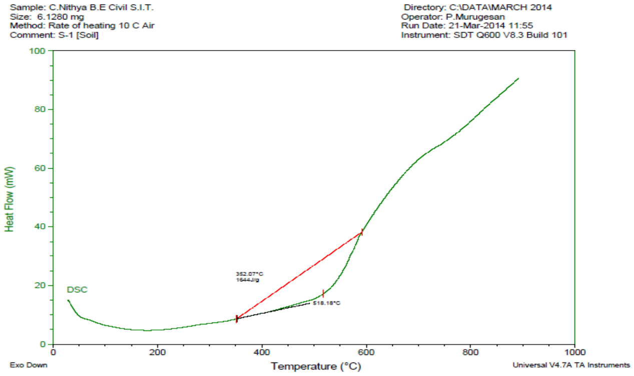


FIG 7.1.2 BLACK COTTON SOIL

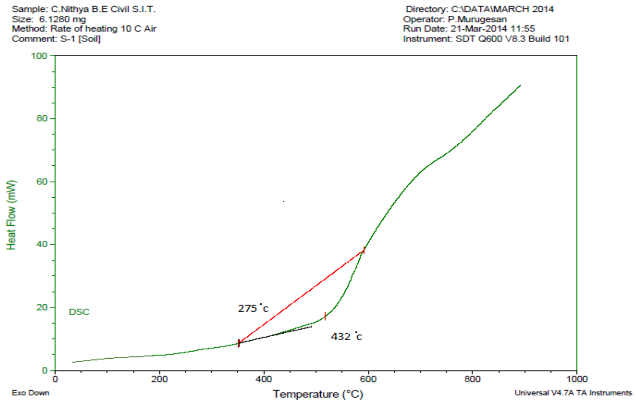


FIG 7.1.3 SAND

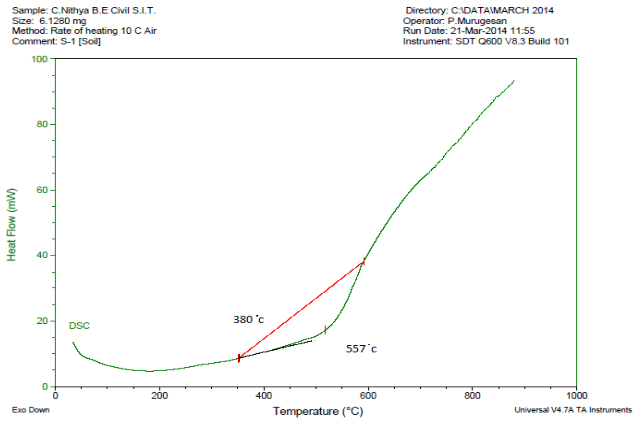


FIG 7.1.4 RED SOIL

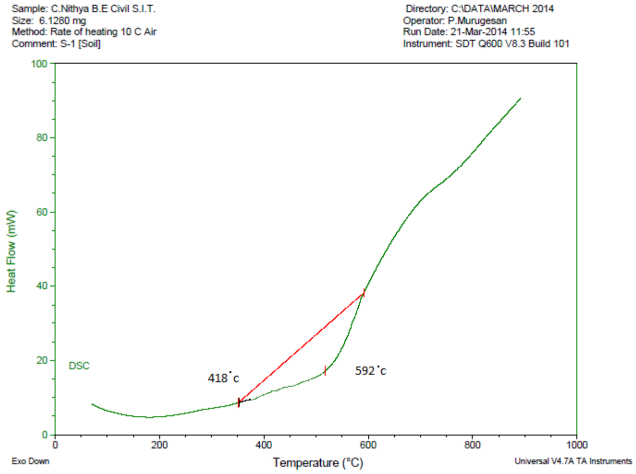
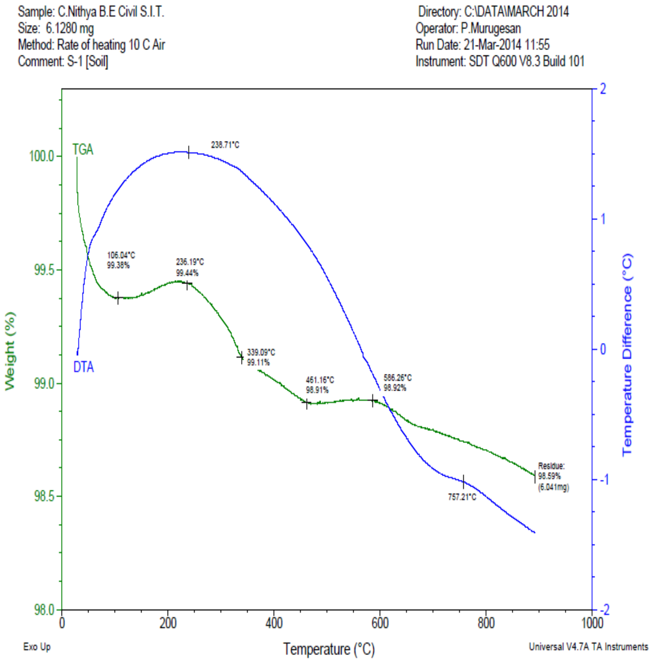


FIG 7.1.5 TEMPERATURE Vs WEIGHT(%)



DSC - DIFFERENTIAL SCANNING CALORIMETER

DTA - DIFFERENTIAL THERMAL ANALYSIS

TGA - THERMO GRAVIMETER ANALYSIS

TEMPERATURE(°C)	**RESULT**
106.04°C-236.19°C	Dehydration of water
236.19°C-339.09°C	Decomposition of organic matter
339.09°C-461.16°C	Decomposition/Oxidation of Carbon released
461.16°C-586.26°C	Observed due to air. It is absent for inert gas.
586.26°C-RESIDUE	Stable region

8.ELECTRICAL RESISTIVITY USING MEGER

To measure the electrical resistance of the moist insulation material, a simple electrical circuit and an ohmmeter with measuring range to 20000 m ohm are used. The specimen is a cylinder with 25 mm diameter. Two nails are entered into the sides of the moist specimen and ohmmeter electrodes are in contact with these nails. The nails' tip have a distance of 10 mm from each other and just 2 mm of their tips are in contact with specimen and the remained are insulated with a layer of tape. The mass and electrical resistance of saturated specimen which is in contact with ambient is measured in different times.

TABLE 8.1.1. ELECTRICAL RESISTIVITY FOR CLAY SOIL

Moisture content (m %)	Ohm (Ω)
6	450
8	300
10	200
12	125
14	100

TABLE 8.1.2. ELECTRICAL RESISTIVITY FOR RED SOIL

Moisture content (m %)	Ohm (Ω)
6	175
8	100
10	50
12	25
14	20

TABLE 8.1.3. ELECTRICAL RESISTIVITY FOR BLACKCOTTON SOIL

Moisture content (m %)	Ohm (Ω)
6	350
8	175
10	75
12	50
14	45

TABLE 8.1.4 ELECTRICAL RESISTIVITY FOR ALLUVIAL SOIL

Moisture content (m %)	Ohm (Ω)
6	325
7	100
8	75
9	60
10	50

TABLE 81.5. ELECTRICAL RESISTIVITY FOR RIVER SAND

Moisture content (m%)	Ohm (Ω)
6	200
8	100
10	75
12	50
14	45

IV.RESULT AND DISCUSSION

The initial weight loss from room temperature to 106˚c is which due to dehydration of water molecules in the samples further an increase in temperature from 106˚c to 236˚c leads to increase in weight loss around 10% on account of closely packed structure the magnitude of weight loss 236.19˚c is higher than 106˚c which confirm the closely packed structure occurs in the region

The decomposition of organic matter decomposition of carbon released and carbon oxidation is revealed from the weight loss in the region 236˚c -339˚c and 339˚c -461˚c. In addition the weight. Loss occurred from 461˚c -586˚c is occurred due to calcination of the sample carried out at atmospheric air further the weight loss beyond 586˚c indicates that the clay compound transformed into more stable crystal structure

V.CONCLUSION

We compared the red soil, black cotton soil, clay soil, alluvial soil, sand and we found the results

Thermal conductivity of red soil is maximum and thermal conductivity of clay soil is minimum. The value of thermal conductivity of red soil is 2.25 w/m.k and the value of clay soil is 1.45 w/m.k

Electrical resistivity of clay soil is maximum and electrical resistivity of red soil is minimum. The value of electrical resistivity of clay soil is 450 ohm and the value of red soil is 175 ohm.

Thus we conclude that the thermal conductivity and electrical resistivity are inversely proportional.

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