Impact of temperature and moisture on thermal conductivity and diffusivity of stones using one dimensional steady state heat flow: An experimental study

Rahul Sharma

Department of Mechanical Engineering,

G. L. Bajaj Institute of Technology & Management, Greater Noida,

ABSTRACT

The thermal conductivity of materials is an important physical property that must be considered in most applications involving the transport, exchange, or conversion of thermal energy. Thermal conductivity is of particular importance in the design and fabrication of insulation and other building materials. For earth materials, thermal-conductivity data are necessary in the determination of the rate of heat loss from underground steam and hot water pipes. An Experimental study was carried out to investigate the impact of temperature and moisture on thermal conductivity and thermal diffusivity of stones. One dimensional steady state technique is used to find out the thermal conductivity of limestone, sandstone, marble, granite, slate. It might be seen that thermal conductivity in all cases decreases with temperature over temperature range 40 to 100 °C. Due to moisture content, thermal conductivity of stone slightly increases due to absorption of water particles. Variation of c values for stone have been indicated which shows that it increase with temperature. It might be also seen that thermal diffusivity decreases with temperature and increases with moisture content over range 40 to 100°C. The reason is that with increasing temperature thermal conductivity reduces and specific heat increase, however the reduction in thermal conductivity is more than increase in heat storage capacity. It has been found that due to moisture content (water sorbed particles) k value increases and hence thermal diffusivityincrease.

Keywords*: *Thermal Conductivity, Thermal Diffusivity, Moisture Content

I INTRODUCTION

Heat transfer is the study of thermal energy transport within a medium or among neighboring media by molecular interaction, fluid motion, and electro-magnetic waves, resulting from a spatial variation in temperature. This variation in temperature is governed by the principle of energy conservation, which when applied to a control volume or a control mass, states that the sum of the flow of energy and heat across the system, the work done on the system, and the energy stored and converted within the system, is zero. Heat transfer finds application in many important areas, namely design of thermal and nuclear power plants including heat engines, steam generators, condensers and other heat exchange equipments, catalytic convertors, heat shields for space vehicles, furnaces, electronic equipments etc., internal combustion engines, refrigeration and air conditioning units, design of cooling systems for electric motors generators and transformers, heating and cooling of fluids etc. in chemical operations, construction of dams and structures, minimization of building heat losses using improved insulation techniques, thermal control of space vehicles, heat treatment of metals, dispersion of atmospheric pollutants. A thermal system contains matter or substance and this substance may change by transformation or by exchange of mass with the surroundings. To perform a thermal analysis of a system, we need to use thermodynamics, which allows for quantitative description of the substance. This is done by defining the boundaries of the system, applying the conservation principles, and examining how the system participates in thermal energy exchange and conversion.

II OBJECTIVE AND METHODOLOGY

Experimental study involves effect of temperature and moisture on the thermal conductivity and thermal diffusivity of Stone. Use steady state one dimension heat transfer to measure the thermal conductivity by applying Fourier law of heat conduction. It use a wooden box, as wood having lower thermal conductivity so its works as an insulator. Stone sample of 152.4 mm square and having thickness of 10mm is used and heat is conducted through this sample by using rubber silicon heater. Sample is placed on heater keeping no air gap b/w specimen and heater so that heat is conducted only by conduction. Sides of the sample are insulated using insulation (glass wool) so that heat is conducted along one direction (in the direction of thickness).Steady state operating condition exists since temperature reading does not change with time .Heat losses through the lateral surfaces of the apparatus are negligible since those surface are well insulated. Two Thermocouple are embedded into each sample some distance L apart, and differential thermometer reads the temperature drop ΔT along each sample. When steady state condition is reached, the total rate of heat transfer through both samples becomes equal to the electric power drawn by the heater. As rate of heat flow, ΔT, L and Area of sample through which heat transfer occur are known so thermal conductivity can be determined c value for stone have been calculated by,Q= mc ΔT .Q is heat supplied. Q has been calculated from voltmeter and ammeter reading, as Q varies there is also variation in specific heat. Variation of c with temperature has been indicated.,$c = \frac{Q}{m\Delta T}$.Thermal diffusivity have been calculated from,$\alpha = \frac{k}{\rho c}$.As there is variation in thermal conductivity with temperature due to which thermal diffusivity of stones also varies.

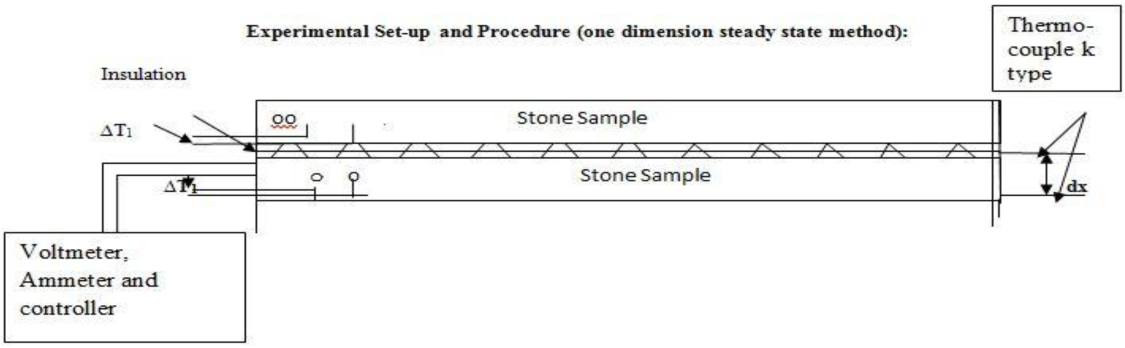


Figure 1 : Set up

Stone Sample Diagram

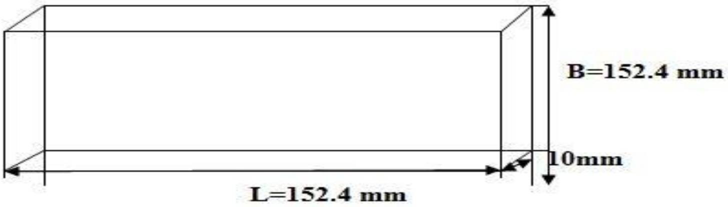


Figure 2 : Stone sample.

The thermal conductivity of a material is to be determined by ensuring one-dimensional heat conduction, and by measuring temperatures when steady operating conditions are reached.

III EXPERIMENTAL SET-UP

Figure3: Experimental Set-up

Table1:Model Specification

Model	Applied Research and Engg. Pvt. Ltd.
Voltmeter	230 V
Ammeter	30 Amp
Controller	Percentage Calibration Approximate 0-260
Wooden Box Dimension	20.32*20.32*20.32 cm^3
Thermocouple	K type
Insulation	Glass Wool

Table2: Heater Specification

Model	Marathon Make Flexible Silicon Rubber Heater with inbuilt Thermostat
Size	6 " width * 6" length
Voltage	230 V
Wattage	350 W

IV RESULTS & DISCUSSION

Variation of thermal conductivity (K)with temperature:

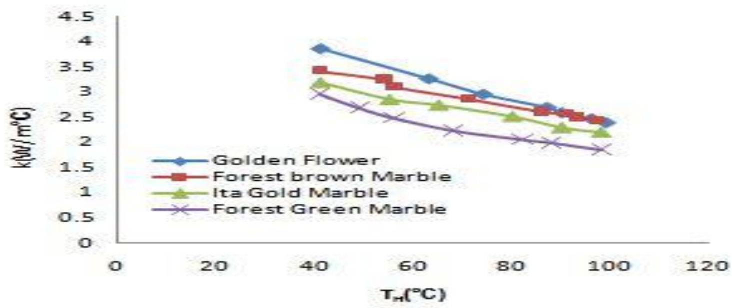
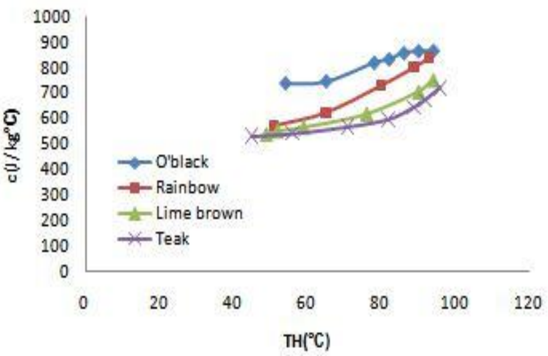


Figure4: variation of K in marble with heater temperature

The metallic solid transport of thermal energy is due to two effects: the migration of free electrons and lattice vibration waves but in case of non metallic solid (Marble) it is due to lattice vibration only. As temperature increases lattice vibration increases due to which thermal conductivity reduces. Fig. 4 shows that Thermal conductivity is highest in case of golden flower because it contain higher % of moisture content then other stone sample

Variation of specific heat(c) with temperature:



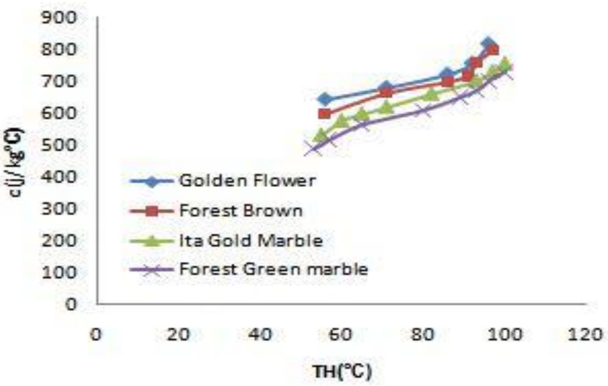


Figure5: variation of c in marble with heater temperature**Figure6:** variation of c in marble with T_H

Fig. 5 shows that Specific heat in case of o'black is highest because it contains larger moisture content than other stone sample. As a result of this large amount of heat is required to cause the same temperature change.Fig. 6 shows that Specific heat in golden flower is higher because it contains larger moisture content than other stone (Marble) sample. As a result of this large amount of heat is required to cause the same temperature change

Variation of thermal conductivity with moisture content:

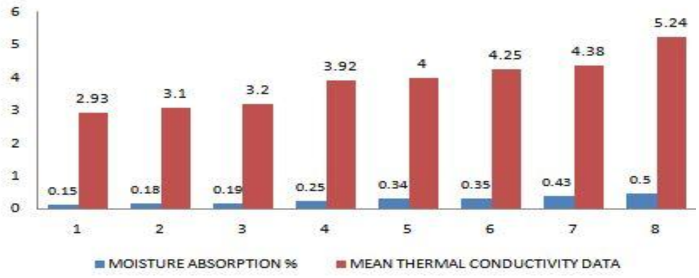
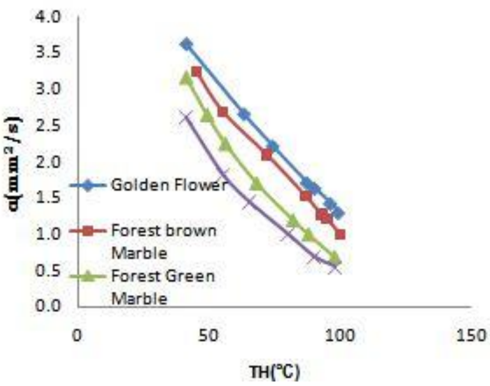


Fig7: shows the values of thermal conductivity and moisture content for different stones. The highest thermal conductivity is obtained in case of o'black (granite)

Variatioin of thermal diffusivity(α) with temperature:



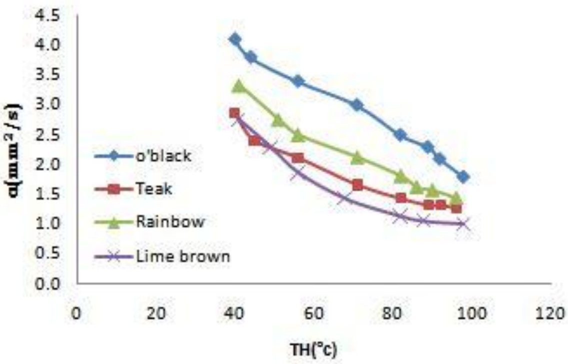


Figure8: variation of α in marble with heater temperature **Figure9:** variation of α in marble with heater temperature

Fig. 8 shows that as the temperature increases thermal conductivityof marble decreases and hence thermal diffusivity decreases over the temperature range 40-100°C.Thermal diffusivity of golden flower is highest among four stone(marble) samples.Fig.9 shows that as the temperature increases thermal conductivity decreases and hence thermal diffusivity decreases over the temperature range 40-100°C.Thermal diffusivity of o' black is highest among four stone samples

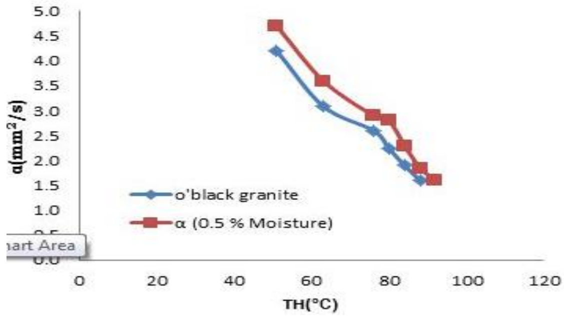


Fig. 10: shows that there is increase in thermal diffusivity due to moisture content because moisture contains water particles and water having high thermal conductivity. It value varies over (1.7-4.1) without moisture and (2-4.5) with moisture over the temperature range 40-100°C.

Figure10: variation of α in marble with heater temperature

V CONCLUSION

Thermal conductivity is calculated for stone samples. It value varies over the range of (4-5.1) in marble, 5.2(granite), 5.4(slate), 4.4 (sandstone), 3.13(limestone) .It is concluded that thermal conductivity in all cases decreases with temperature. Due to moisture content, thermal conductivity of stone slightly increases. It is concluded that thermal diffusivity decreases with temperature and increases with moisture content over range 40 to 100°C. The reason is that with increasing temperature thermal conductivity reduces and specific heat increase, however the reduction in thermal conductivity is more than increase in heat storage capacity. It is also concluded that due to moisture content (water sorbed particles) k value increases and hence thermal diffusivity increases.

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