Sub-Sahara African Academic Research Publications
September, 2022 Editions

JAAS
Journal of African Advancement & Sus. Studies
Vol.25, No.2, ISSN: 3125-5521

STUDY OF THERMAL PROPERTIES OF SOME COMMON ROOFING MATERIALS (ALUMINUM AND POLYCARBONATE SHEET) USED IN BUILDING

MOHAMMED JAFARU; BUBA MOHAMMED; & ISHAKU HAMIDU MIDALA
Department of science laboratory Technology Federal polytechnic Mubi

Abstract
This research work is focused on determining the thermal properties of some selected roofing materials used for roofing; these materials are aluminium sheets and polycarbonate sheets. In this project work, Lee-Charton's method is used to achieve the aim of this research. The result obtained shows that, polycarbonate sheet is a good insulating material and aluminium is a good conductor of heat where the polycarbonate has a thermal conductivity of 0.20 w/mK, thermal diffusivity of 0.00014 m2/s, and also a thermal resistance of 5.00 mk/w. Likewise aluminium has a thermal conductivity of 205.2 w/mK, thermal diffusivity of 0.0018 m2/s, and also thermal resistance of 0.0049 mk/w. The best material to be used in the Mubi Adamawa state is polycarbonate. However, from the economic point of view, it is recommendable to choose an insulating material with a lower thermal conductivity and more affordability to the average number of inhabitants when considering housing and school construction in a densely populated town like Mubi.

Keywords: *thermal properties, Aluminium, thermal conductivity*

INTRODUCTION
The thermal properties of a material are those properties that are related to the conductivity of heat. In other words, these properties are exhibited by a material when heat passes through them. The thermal property of

material decides how it reacts when it is subjected to heat fluctuation excessive heat or very low heat. Roofing materials are overhead exterior surfaces that can cover the upper limits of the room. They are not generally considered structural elements but finished surfaces concealing the underside of room structure or the floor of the store above. However, the knowledge of the thermal properties of different materials is very important in the choice of the types of materials to be used as a radiant barrier since the heat flow through any building depends on the thermal properties of the materials used in the building (Etuk et al., 2007). The study of the thermal properties of materials will help us to know whether materials are suitable to use as roofing materials in our houses, school and industries.

The provision of housing among other social amenities occupies a strategic position in most development plans for developing Nations such as Nigeria (Chukwucha, and Owate, 2002). One of the fundamental requirements of buildings is the protection of the people who live and work within them from harsh weather. Thus, the objective of environmental building design is the creation of a comfortable yet efficient internal environment (Camilleri, 2000). The design of the building envelope is crucial for attaining an optimal configuration, which responds effectively to environmental changes to reduce their impact. The understanding of energy-related characteristics and the evaluation of the relevant properties of the building envelope is an integral part of every environmental assessment. Solar energy affects significantly, the interior environment and the energy requirements of buildings. (Lattimer & Ouelletes, 2006).

However, one way to reduce the heat flux is the use of radiant barriers which reduce the heat flux through radiation. Most building materials particularly, roofing materials are good conductors of heat. Materials like metal and tile are commonly used in the form of sheet metal for roofing in building construction. The knowledge of the thermal properties of different roofing materials is very important in the choice of the type of material to be used in the construction of a self-cooling or passively cooled building design. (Etuk, et al., 2008 & Michael, et al., 2008). Therefore, thermal insulation is applied above the ceiling to achieve the thermal resistance requirements. The requisite thermal resistance can be achieved by adding additional layers of fibrous loft insulation or with reflective foil layers to create air spaces or by making use of thermally insulating board products (Safintra roofing and steel South Africa, 2016). A recent observation has shown that roofing materials used in building design don't take sufficient account of climate and environmental factors in the design, most especially about the choice of roofing materials to be used. These situations would increase the energy consumption for heating and cooling in buildings and affects comfort, health and efficiency. Therefore, it is important to carry out adequate research on the thermal properties of these roofing materials. The interest of this study is borne by the fact that the climate comfortability of the people lies solely in the use of suitable insulating materials in their respective homes and place of work. The use of thermally insulating material will reduce the penetration of heat into the building, therefore reducing the demand for air-conditioning. This, therefore, prompts the call for investigating the thermal properties of insulating material used for roofing for its suitability and usage in building construction.

REVIEW OF PREVIOUS WORK

Raheem's (2015) Investigation was carried out to evaluate the effect of various types of building roof materials on the cooling load. This study involved selecting a particular building type (factory building) and the effect of the cooling load by using various metal deck roofing with and without insulation. The case study in this project is a simple factory building consisting of two floors, the ground floor is a production space and the first floor is the factory's offices. The cooling load requirement for the building was calculated by using Auto desk Revit software. The results indicated that roof insulation is one of the most important strategies to reduce the cooling load and enhanced the electricity consumption in the building, 20% reduction in space cooling leads to cost savings and reduces the emission of gases that pollute the environment directly. (Safintra Roofing and steel South Africa and the safari group, 2017) investigated the thermal performance of steel roofing and cladding materials for the residential and formal sector market in the RSA, the research was conducted using three samples; clay tiles, cement tiles and steel sheeting. However, the comparative study of the thermal resistance performance of this sample was computed. The result shows that the thermal capacity of clay tiles is greater than that of a profiled metal roofing but is of little consequence as the heat required to bring the tile up to the same temperature as a metal roof will arrive at the surface of the roof in a matter of minutes, and thereafter it will re-radiate a similar level of solar radiation heat into the roof cavity. Therefore, Steel roof sheeting will give superior thermal resistance performance, if correctly designed with reflective foil insulation systems.

The difference is equal to the thermal resistance of 29mm of fibreglass roll insulation. (Owate et al., 2007) Thermal conductivities of copper, aluminium and brass materials have been determined using a system designed, constructed and tested. The system is a modified form of Smith's thermal conductivity apparatus which has been widely applied in the normal laboratory. It consists of a heating chamber (made by sandwiching heating coil within ceramic thermal insulators), a sample holder region and the cold end area. The thermal conductivities of copper, aluminium, and brass were measured using the system and the results obtained were compared statistically with other standards. It was observed that the measured thermal conductivity values were 397.4 ± 2.2, 238.0 ± 1.3 and 110.2 ± 1.2 Wm-1 K-1 for copper, aluminium and brass respectively. These results compared relatively well with other standard values. Such values are in order 396,236 and 109 Wm-1K-1. The results obtained certified the aim of the work which was to fabricate a thermal conductivity measurement system suitable for data collection and experimental experience in a developing economic environment. Consequently, the analysis shows that the device can be reproduced for thermal conductivity measurements in a developing laboratory experimental environment

MATERIALS

Materials used to carry out this research work are given in table 1 below.

Table: 1. List of materials/Equipment used.

S/N	Material/equipment	Quantity
1	A circular disc of the two predominantly roofing materials: Aluminum and polycarbonate sheet.	Aluminum = 3mm Polycarbonate sheet = 3mm
2	Vanier Caliper	0.01mm
3	Micrometer Screw Gauge	100mm

4	Weighing Balance	Up to 1gm
5	Retort Stand	80 cm
6	Heat Source: Stove	Hot flame
7	Steam boiler container water	100°C atmosphere pressure
8	Two thermometers in the 100°C range	80°C to 100°C range
9	Stopwatch	Count down timer
10	Lee – Charlton Apparatus	Steady-state techniques

SAMPLE PREPARATION

Each sample was cut with the aid of scissors, and the length of each sample was measured with a Venire caliper and recorded. The thickness and the size (breadth or width) were measured with a Micrometer screw gauge and recorded. The composite sample has been prepared by using hand-lay-up techniques to measure the thermal conductivity (using Lee-Charlton Apparatus) the diagram below is a sample shape with a dimension of 11.5mm in diameter and thickness of 3mm.

METHODS

Lee-Charlton Apparatus is the method used to measure the thermal conductivity of the two samples, and the experimental set-up is as shown in figure 1 below.

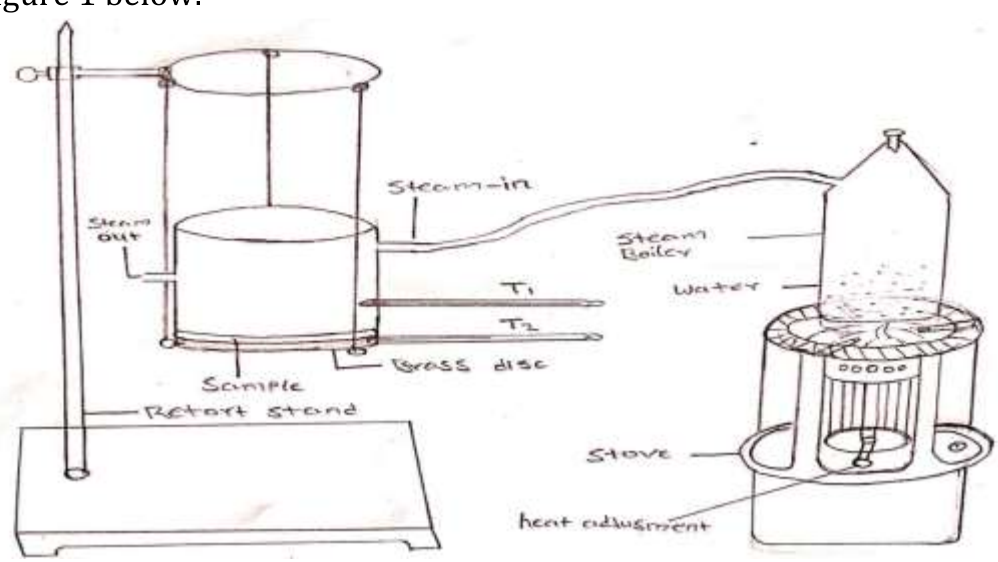

Figure: 1 Experimental Set-up of Lee-Charlton's Method in Determination of Thermal Conductivity

PROCEDURE

The two sample materials used as roofing materials in a building which include: Aluminum and polycarbonate sheet were collected from the building material shop, the sample was shaped to have an equal cross-sectional area or to take a dimension of Lee-Charlton Apparatus. The diameter of each sample was measured using a Vanier caliper and the thickness was measured using a micrometer screw gauge. The set-up was then rearranged as shown in Fig 3.5 the steam boiler was filled with water to nearly half and heated to produce steam that can cause the rise in temperature of the brass disc and sample specimen until steady temperatures of T1 and T2 were obtained after a certain time interval.

The specimen was then removed and the brass disc was heated directly by the steam chamber till its temperature was slightly above T1. The steam chamber was then removed and the sample specimen was placed on the brass disc. The initial temperature was noted and the cooling temperature drop was recorded continually for one minute till there was no observable change in the temperature

RESULT OF SAMPLE DIMENSIONS AND MASS MEASUREMENT

The mass of each sample was measured with a weighing balance and their dimensions were also measured with the aid of a micrometer screw gauge and the Vanier Caliper. The results are presented in Table 1 below.

Table 2: Sample Mass and Dimensions.

Sample	Thickness (m)	Mass (Kg)	Diameter (m)	Area (m^2)
Aluminum	0.0042	0.00124	0.009	0.128
Polycarbonate sheet	0.0042	0.00095	0.009	0.128

Results obtained and shown in the table above are used to obtain other parameters needed for this research work.

Below is a table showing the constant specific heat capacity of the samples.
Table 3: Constant Specific heat capacity of the materials

Sample	Specific Heat Capacity (j/kgk)
Aluminum	421.045
Polycarbonate sheet	1.212

Table 4 Result of T1 and T2 of the samples

Sample	T_1	T_2
Aluminum	100° C	65° C
Polycarbonate sheet	100°C	54° C

Test and analysis of results

Table 5 Cooling rate of the samples
Ambient Temperature = 28°C

Time in Minutes	Aluminium	Polycarbonate sheet
0	98	88
1	94	84
2	87	79
3	84	75
4	82	70
5	79	67
6	77	63
7	76	59
8	74	56
9	70	50
10	69	47

Therefore using the equations 2.4, 2.5, and 2.6 above the thermal properties of the two samples were calculated and recorded as given in table 5 below.

Table Thermal properties of the aluminum and polycarbonate sheet.

Thermal Properties	Samples	
	Aluminum	Polycarbonate
Density (kg/m³)	2700	1200
Thermal Conductivity (k)(w/mk)	205.2	0.20
Thermal Diffusivity (λ) (m^2/s)	0.0018	0.00014

Thermal Resistivity (r) (k/w)	0.0049	5.00

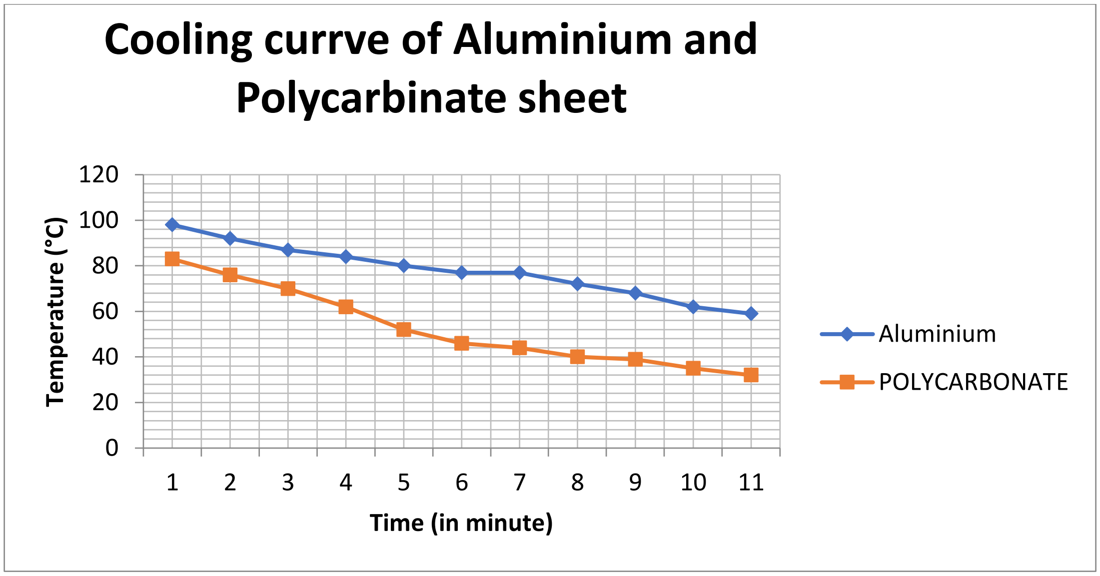

Fig 2 Cooling Curve of Aluminum and Polycarbonate.

DISCUSSION

As shown in the table above, the sample mass and dimension of the two (aluminum and polycarbonate) selected materials showing their thickness, area, mass, and diameter of the chosen sample as given in table 2. That is because thermal conductivity is a function of thickness and area. The samples were prepaid in equal thickness and cross-sectional area. Also, the initial temperature (T_1) and final temperature (T_2) of both samples during the experiment were recorded in table tab 4 while the sample's specific heat capacity is given in tab 3 respectively.

Table 5 and Figure 2 show the cooling rate of the three selected materials at an ambient temperature of 28°C. The results reveal that within the curve of the prevailing test polycarbonate exhibits the best cooling rate. Also, table 4.5 gives the calculated thermal parameter such as thermal conductivity, K; thermal diffusivity, and thermal resistivity, r for the three selected materials. The result shows that polycarbonate sheet is a good insulating material and aluminum is a good conductor of heat where the polycarbonate has a thermal conductivity of 0.20 w/mK, thermal diffusivity of 0.00014 m^2/s, and also a thermal resistance of 5.00 mk/w.

Likewise aluminum has a thermal conductivity of 205.2 w/mK, thermal diffusivity of 0.0018 m^2/s, and also thermal resistance of 0.0049 mk/w. Theoretically, a substance with a large thermal conductivity value is a good conductor of heat, one with a small thermal conductivity value is a poor heat conductor that is a good insulator. Thermal diffusivity, therefore, increases with the ability of a body to conduct heat and decreases with the amount of heat needed to change the temperature of a body. It is of little interest in many thermal insulation systems since, in these, approximately steady state conditions normally exist.

CONCLUSION

In conclusion, the thermal conductivity of the selected roofing material used in building under this investigation from the result in Table 4.5 we have observed that among the materials studies, polycarbonate provides the best thermal insulation since it has the lower thermal conductivity with (highest thermal resistivity) followed by Aluminum from the result of the research. The best material to be used in the Mubi Adamawa state is polycarbonate. However, from an economic point of view, it is commendable to choose an insulating material with a lower thermal conductivity and more affordability for the average number of inhabitants when considering housing and school construction in a densely populated town like Mubi.

RECOMMENDATIONS

1. The builder should concentrate more on the insulator with good thermal efficiency when they come to the selection of roofing material in the building.
2. Best on the experience we gained in this research we suggest that polycarbonate is the best roofing insulator material in building.
3. We recommend the management of Federal Polytechnic Mubi modernize the office, laboratory, and lecture halls that have roofing that is not good in terms of thermal efficiency and stop using them purposely for the benefit of the lecturer and student.

REFERENCES

Alam, M., Rahman, S., Holder, A., Raquib, P.K. and Hasan, M. (2012). Lee-Charlton method for investigation of thermal conductivity of insulating materials. IOSR Journal of Mechnical and Civil Engineering (IOSR – JMCE), issue Sept. to Oct., PP 53-60.

Emmanuel, B.E., Jerome, G., Egbe, S.A., Takim, U., Akpan, P. and Everest, B. (2016). Investigation of the thermal conductivity of polyvinyl chloride Ceiling Material Produced in Epz Calabar for application tropical climate zones. Journal of Polymer and Textile Engineering (IOSR-JPTE), Issue 2, PP 34-38.

George N.J, Obianwu V. I, Akpabio G.T and Obot I.B. (2010). Comparison of thermal Insulation efficiency of some select materials used as ceiling in building design, Archives of Applied Science Research, 2 (3): 253-259.

Gesa, F. Newton, Atser A. Roy and Aondoakaa I. Solomon. (2014). Investigation of thermal Insulation Properties of selected ceiling materials used in Makurdi Metropolis (Benue State-Nigeria.), American Journal of Engineering research (AJER), Issue 11, pp. 245-250.

Michel's, Lamberts C, R. and Guths S. (2008). Theoretical/Experimental comparison of Heat Flux reduction in roofs achieved through the use of reflective thermal insulators, Journal of energy and buildings, 40(4), 438-444.

Mohammed Abid Ali, V. V. S. Kesava Rao and S. Raj pal singh. (2010). Determination of thermal Conductivity of plaster of Paris, International eJournal of Mathematics And Engineering 52, 528 – 531.

Ndupu, Okeke, Ladipo. (2000). Senior Secondary Physics 1. (New edition). Kind College, logos, Pp 50 – 52.

Novo A. V, Bayon J.R, Castro-Fresno D and Rodriguez-Hernandez J. (2010). Review of Seasonal heat Storage in large basin: water tanks and gravel water Pits Applied Energy, 87: 390, and 397.

Ramesh Chandra Mohapatra, Antaryami Mishra andBibhuti Bhushan Choudhury. (2014). Experimental study on thermal conductivity of teak wood dust reinforced Epoxy composite using lee's apparatus method, International journal of Mechanical Engineering applications, 2(6): 98-103.

Raymond A. Serway, Jerry S. Faugn. (1989). College physics second edition, published by sunders College, p p 277 to 282.

TIASA (2001). Thermal insulation Association of Southern Africa, agamas publisher

Twidell, J. and weir, p. (1990). Renewable energy resources. London, E and F.N Spoon, 418.