IOSR Journal Of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 17, Issue 3 Ser. 2 (May. – June. 2025), PP 17-21
www.Iosrjournals.Org

Determination Of The Thermal Properties Of Some Selected Materials Used As Ceiling In Building At Ishiagu, Ebonyi State, Nigeria

Nwokporo Ifeanyi Emmanuel, Sampson Nsimoh Michael,
Ezenwogene Roy Chima, Chukwueke Jude Izuchukwu, Obiana Ebele Chioma.
[1,4,5]Department Of Science Laboratory Technology, And [2,3]Department Of Agricultural And Bio-Environmental Engineering Technology, Federal College Of Agriculture, Ishiagu Ebonyi State Nigeria.

Abstract
This study investigates the thermal properties of four common ceiling materials; PVC, POP, asbestos and cardboard used in buildings in Ishiagu, Ebonyi State, Nigeria. The aim was to determine the thermal conductivity, specific heat capacity and thermal resistance of these materials to assess their effectiveness in insulating against heat in tropical climates. The experimental results revealed that asbestos exhibited the lowest thermal conductivity (0.09 W/m·K) and the highest thermal resistance (11.11 m²·K/W), making it the best thermal insulator. However, due to its associated health risks, asbestos is no longer suitable for use. Cardboard, with the highest specific heat capacity (1800 J/kg·°C), proved to be a viable alternative despite its lower thermal conductivity. PVC and POP demonstrated inferior thermal performance, with PVC slightly outperforming POP. The study concludes that while asbestos remains the most effective material, safer alternatives like cardboard, with proper treatment, should be considered in future building designs. Recommendations were made for further research into sustainable, non-toxic materials to enhance energy efficiency in building construction.
Keywords: *Ceiling materials, thermal conductivity, specific heat capacity and thermal resistance.*

Date of Submission: 27-05-2025 | Date of Acceptance: 07-06-2025

I. Introduction

Ceiling materials are overhead interior surfaces that can cover the upper limits of the room. They are not generally considered as structural element but finished surfaces concealing the underside of room structure or the floor of store above. In Nigeria, the use of zinc made roofs without ceilings are very common, thus there is intense heat transfer to the internal environment, which may cause thermal discomfort to the inhabitants [3]. One way to reduce the thermal discomfort is by the use of radiant barrier (i.e. ceiling board) which reduce the heat flux.

However, the knowledge of 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 use in the building [3]. The study of the thermal properties of materials will help us to know whether materials are suitable to use as Ceiling materials in our houses, schools and industries. Heat propagated in the interior spaces in buildings through roofs and walls and partly through Ceiling panels by the process of conduction and radiation [5]. This is because the common materials used as roofing sheets are materials like zinc and aluminum which have high thermal conductivity [7]. To reduce the intensity of this heat, there is need to use materials of tolerable thermal responses as ceiling materials in buildings. Good insulating materials will have high value of thermal resistivity. This implies that, different type of ceiling materials will have different thermal behaviors. Insulator is a material or devised used to inhibit or prevent the conduction of heat or electricity [6].

In building construction, ceilings play a critical role in enhancing thermal comfort by acting as a barrier to heat transfer between the roof and indoor spaces. The selection of appropriate ceiling materials is particularly important in tropical climates, such as Ishiagu, Ebonyi State, Nigeria, where high temperatures and humidity levels prevail [2]. Thermal properties, including thermal conductivity, specific heat capacity, and thermal resistance, influence the ability of ceiling materials to regulate indoor temperatures and improve energy efficiency.

Ceiling materials like PVC (polyvinyl chloride), POP (plaster of Paris), asbestos and cardboard are commonly used in Nigeria due to their availability, cost-effectiveness and varying thermal properties [4]. However, their performance in terms of heat transfer and insulation varies significantly, making it essential to evaluate their thermal properties in the context of local climatic conditions. The demand for energy-efficient building designs has increased in recent years, driven by concerns about rising energy costs and climate change. Effective insulation provided by ceiling materials can reduce reliance on artificial cooling systems, leading to lower energy consumption and enhanced indoor comfort [1].

The primarily function of insulator in buildings are: To conserve energy, to reduce heat loss or heat gain, to maintain a temperature condition, to maintain the effective operation of equipment or chemical reaction, to assist in maintaining product at constant temperature, to prevent condensation, to create comfortable environmental condition and protect personnel. Insulation reduces heat transfer through the envelope in building. Whenever there is a temperature difference, heat flows naturally from a warmer space to a cooler space. To maintain comfort in winter (the coldest season of the year), the heat lost must be replaced by the heating system; and in summer (the warmest season of the year), the heat gained must be removed by the cooling system. Therefore, it makes sense to study the thermal properties of insulator in order to reduce gains or loss of energy in buildings and to increase comfortable condition in houses, schools and industries.

[9] justified that, the thermal insulation is provided by embedding insulation materials at least on the roof areas and the vertical walls of the systems. Insulating materials are usually made in various types with different design which lead them to categorize into good and bad insulators on their properties. In this work, emphasis is laid on the study and comparison of thermal properties of some selected materials which include PVC, POP, asbestos and cardboard used as ceilings in buildings. Depending on how large or small the value of their thermal properties, a particular ceiling materials may be more efficient in terms of thermal insulation than another [5].

Observation showed that in this present competitive world, people that are economically favored usually go for the most costly ceiling materials without any preference to the thermal insulation efficiency of such materials. It is based on this observation that this work is designed to investigate and compare the thermal properties of the most frequently used ceiling materials for efficient thermal insulation. This determines the suitability of one ceiling material to another in order to have comfortable thermal condition in buildings.

II. Materials And Methods

Materials and Equipment

The materials and equipment used in this study were stated below.

Ceiling materials

They include: PVC, POP, asbestos and cardboard.

Experimental equipment

i. Thermal Conductivity Meter**:** To measure the rate of heat transfer through each material.

ii. Specific Heat Capacity Apparatus**:** To calculate the heat energy required to raise the material's temperature.

iii. Digital Thermometer**:** To monitor temperature variations.

iv. Weighing Scale**:** To measure material mass accurately.

v. Calipers**:** To determine material thickness.

Sample Preparation

Samples of the ceiling materials were prepared following standardized dimensions for uniformity. Each material was cut into slabs measuring 10 cm × 10 cm × 2 cm. The samples were cleaned and stored in a dry environment to prevent contamination or moisture absorption before testing [10].

Experimental Methods

The thermal properties of the materials were determined using the following methods:

Thermal Conductivity Measurement**:** The thermal conductivity (K) was measured using the steady-state method. Each sample was placed between two plates, with one side heated and the other cooled. The heat transfer rate (Q) was recorded and thermal conductivity was calculated using Fourier's Law:

$$\mathbf{k} = \frac{\mathbf{Q}\,.\mathbf{d}}{\mathbf{A}\,.\Delta\mathbf{T}} \qquad \mathbf{1}$$

Where

Q = Heat transfer rate (W)

d = Thickness of the sample (m)

A = Surface area of the sample (m^2)

ΔT = Temperature difference across the sample (°C)

***Specific Heat Capacity Measurement*:** Specific heat capacity (C) was determined using the method of mixtures. Each material sample was heated to a known temperature and then submerged in a calorimeter containing water. The change in water temperature was recorded and specific heat capacity was calculated as:

$$\mathbf{C} = \frac{\mathbf{Mw\,.Cw\,.\Delta Tw}}{\mathbf{Mm\,.\Delta Tm}} \qquad \mathbf{2}$$

Where
Mw = Mass of water (kg)
Cw = Specific heat capacity of water (J/kg·°C)
ΔTw = Change in water temperature (°C)
Mm = Mass of material (kg)
ΔTm = Change in material temperature (°C)

***Thermal Resistance Measurement*:** Thermal resistance (R) was calculated as the reciprocal of thermal conductivity:

$$\mathbf{R} = \frac{\mathbf{1}}{\mathbf{K}} \qquad \mathbf{3}$$

Methods of Data Analysis

Data obtained from the experiments were analyzed using comparative analysis method to evaluate the performance of the materials in terms of insulation efficiency.

Study Area

The study was conducted in Ishiagu, a community in Ivo Local Government Area of Ebonyi State, Nigeria. Ishiagu is characterized by a tropical climate with high temperatures and significant humidity levels throughout the year. These climatic conditions make it a suitable location for studying the thermal performance of ceiling materials in tropical environments [8].

III. Results And Discussion

Results

The experimental results for thermal conductivity (K) of the four ceiling materials were presented in Table 1 and Figure 1, that of the specific heat capacity (C) of the materials were shown in Table 2 and Figure 2 whereas the results for the thermal resistance values of the materials were shown in Table 3 and Figure 3 respectively.

Table 1: Thermal Conductivity of Ceiling Materials

Material	Thermal Conductivity (W/m·K)
PVC	0.19
POP	0.25
Asbestos	0.09
Cardboard	0.15

Table 2: Specific Heat Capacity of Ceiling Materials

Matterial	Specific Heat Capacity (J/kg·°C)
PVC	1200
POP	1500
Asbestos	800
Cardboard	1800

Table 3: Thermal Resistance of Ceiling Materials

Material	Thermal Resistance (m^2·K/W)
PCV	5.26
POP	4.00
Asbestos	11.11
Cardboard	6.67

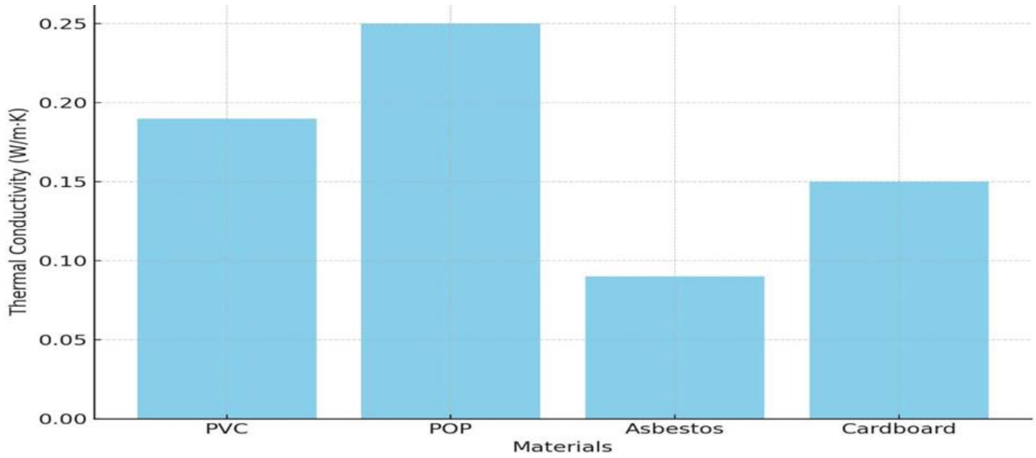

Fig. 1: A bar chart of thermal conductivity against materials.

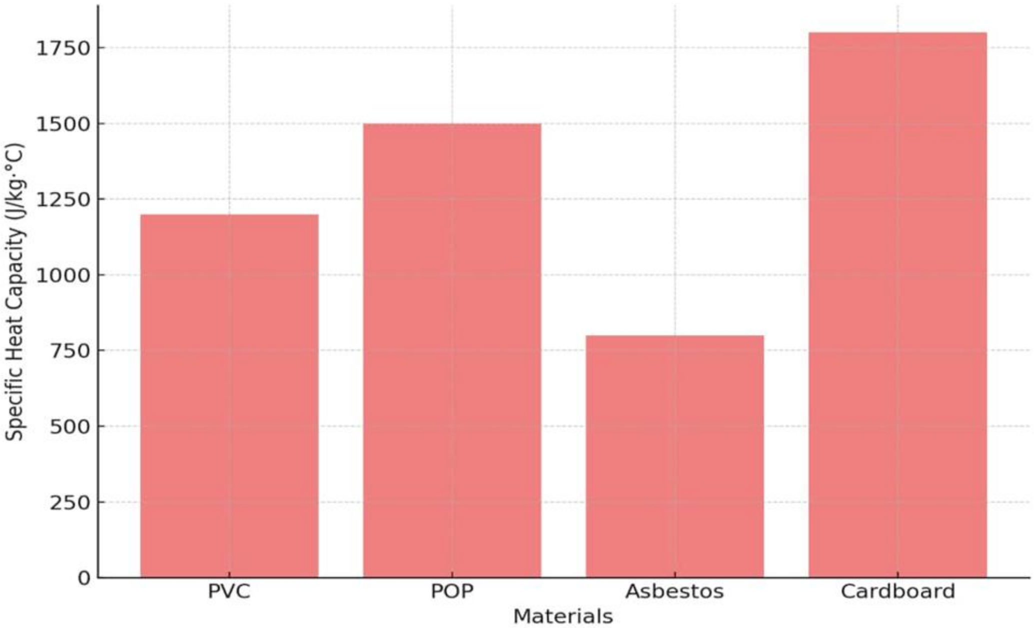

Fig. 2: A bar chart of specific heat capacity against materials.

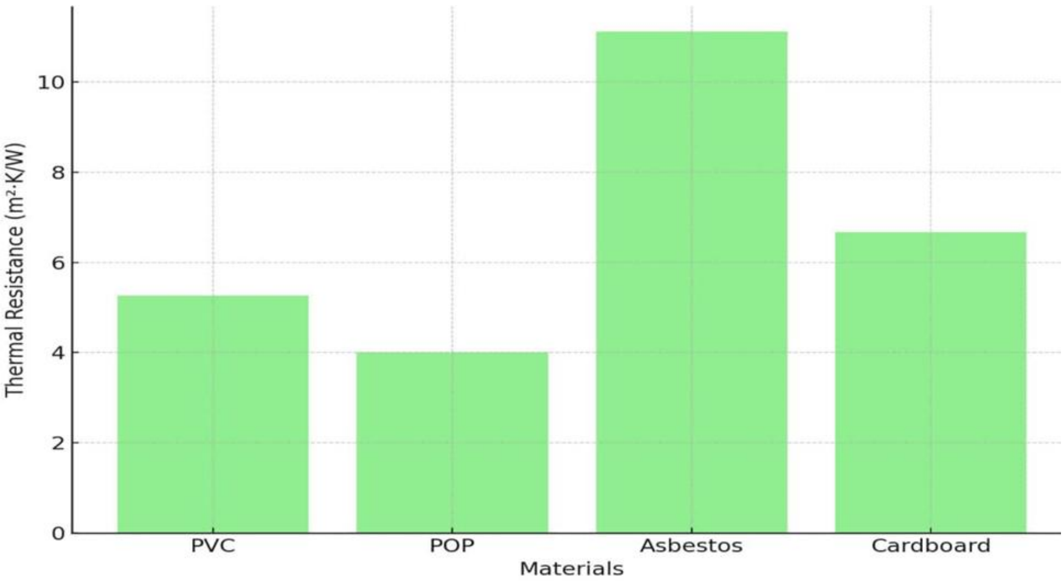

Fig. 3: A bar chart of thermal resistance against materials.

Discussion

As shown in Table 1, asbestos had the lowest thermal conductivity (0.09 W/m·K), indicating the best insulating properties among the materials tested. PVC followed with a value of 0.19 W/m·K, while cardboard (0.15 W/m·K) performed better than POP, which had the highest thermal conductivity at 0.25 W/m·K.

From Figure 1, it is clear that asbestos is the best material for thermal insulation, closely followed by PVC, cardboard and POP. Also, the one with the highest thermal conductivity, is the least efficient in terms of thermal insulation. The bars represent the values of thermal conductivity for each material, with asbestos showing the lowest value, followed by PVC, cardboard and POP.

As indicated in Table 2, cardboard exhibited the highest specific heat capacity (1800 J/kg·°C), meaning it can absorb and retain more heat compared to other materials. POP had the second-highest value of 1500 J/kg·°C, followed by PVC at 1200 J/kg·°C. Asbestos had the lowest specific heat capacity of 800 J/kg·°C, suggesting less effective at heat absorption and retention.

From Figure 2, we see that cardboard stands out as the best material for heat absorption, followed by POP and PVC, with asbestos being the least effective in terms of heat storage. The bars represent the values of specific heat capacity, with cardboard having the highest value, followed by POP, PVC and asbestos.

As shown in Table 3, asbestos had the highest thermal resistance of 11.11 $m^2 \cdot K/W$, followed by cardboard at 6.67 $m^2 \cdot K/W$. PVC had a thermal resistance of 5.26 $m^2 \cdot K/W$ while POP had the lowest value of 4.00 $m^2 \cdot K/W$, confirming its lower insulation efficiency compared to the other materials.

From Figure 3, it is evident that asbestos offers the best thermal resistance, making it the most effective material for insulating ceilings in hot climates. PVC and cardboard follow, with POP providing the least thermal resistance. The bars represent thermal resistance, with asbestos showing the highest thermal resistance, followed by cardboard, PVC, and POP.

Generally, Asbestos was found to have the best thermal conductivity and thermal resistance, though it is hazardous to health. Cardboard exhibited the highest specific heat capacity, making it effective for heat retention. PVC and POP, while commonly used, provided lower insulation efficiency compared to the other materials. The findings suggest that while asbestos remains the best insulator, safer and more sustainable alternatives like cardboard and PVC are more suitable for use in modern construction.

IV. Conclusion

In conclusion, while asbestos is the most effective material in terms of thermal performance, its hazardous health effects make it unsuitable for use in construction today. Cardboard, although not as effective as asbestos, shows promising thermal properties, especially with its high specific heat capacity, making it a viable alternative in certain conditions. PVC and POP, while widely used, offer lower thermal insulation compared to the other materials and may not be the best options for energy-efficient building design.

References

[1] Adebayo, S. A. And Onyekachi, U. A. (2020). Comparative Analysis Of Ceiling Materials For Energy-Efficient Building Design In Nigeria. *Journal Of Building Performance*, 8(1), 23-34.

[2] Akande, O. K. And Adebamowo, M. A. (2010). Indoor Thermal Comfort For Residential Buildings In Hot-Dry Climate Of Nigeria. *Proceedings Of The Conference On Sustainable Architecture And Urban Design*.

[3] Etuk, S. E., Akpabio, L. E And Akpabio, K. E. (2007). Determination Of Thermal Properties Of Cocos Nucifera Trunk For Predicting Temperature Variation With Its Thickness, The Arabian Journal For Science And Engineering, 30(A1), 121-126.

[4] Eze, M. E., Chidiebere, O. C. And Nwankwo, A. O. (2021). Evaluating Thermal Conductivity Of Building Materials In Nigeria: A Case Study. *Journal Of Construction Science And Technology*, 6(3), 45-52.

[5] George, N. J., Obianwu, V. I., Akpabio, G. T. And Obot, I. B. (2010). Comparison Of Thermal Insulation Efficiency Of Some Selected Materials Used As Ceiling In Building Design, Archives Of Applied Science Research, 2 (3): 253-259.

[6] Gesa, F. N., Atser, A. R. And Aondoakaa, I. S. (2014). Investigation Of Thermal Insulation Properties Of Selected Ceiling Materials Used In Makurdi Metropolis (Benuestate- Nigeria.), American Journal Of Engineering Research (AJER), Issue 11, Pp-245-250.

[7] Michael, C. O., Evelyn, O., Ephraim, O. C., Chinedu, E. E. And Great, A. J. (2012). Comparison Of The Thermal Properties Of Asbestos And Polyvinyl Chloride Ceiling Sheets, Materials Sciences And Applications.

[8] NIMET. (2022). Climate Data For Ishiagu, Ebonyi State. Nigerian Meteorological Agency.

[9] Novo, A. V., Bayon, J. R., Castro, D. And Rodriguez, H. J. (2010). Review Of Seasonal Heat Storage In Large Basin: Water Tanks And Gravel Water Pits Applied Energy, 87: 390, And 397.

[10] Olusola, A. O., Adebisi, O. J. And Oyewole, M. K. (2020). Thermal Performance Of Building Materials In Tropical Climates. *Building Research And Information*, 48(5), 341-352.