

Comparative Evaluation of Heat Absorption and Thermal Performance of Selected Roofing Materials Sold at Abakaliki Building Materials Market, Ebonyi State, Nigeria

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ABSTRACT

This study comparatively evaluated the heat absorption and thermal performance of selected roofing materials sold at the Abakaliki Building Materials Market, Ebonyi State, Nigeria. The roofing materials investigated were polycarbonate roofing sheets, galvanized steel roofing sheets, fiber cement roofing sheets, and corrugated roofing sheets. The study was motivated by the need to identify roofing materials that provide better thermal comfort and reduce heat gain in buildings within the tropical climate of southeastern Nigeria. An experimental research design was adopted. Four identical test chambers were constructed and roofed separately with each of the selected materials. Temperature measurements were taken under similar environmental conditions using digital thermometers, and the data were analyzed using descriptive statistics, tables and bar charts. The results showed that galvanized steel roofing sheets recorded the highest average indoor temperature (38.6°C), indicating the highest heat absorption and poorest thermal performance. Fiber cement roofing sheets recorded the lowest average indoor temperature (31.9°C), demonstrating the best thermal insulation performance. Polycarbonate roofing sheets recorded an average indoor temperature of 35.8°C, while corrugated roofing sheets recorded 34.2°C, indicating moderate thermal performance. The study concluded that roofing materials significantly influence indoor temperature and thermal comfort. Fiber cement roofing sheets are the most suitable among the selected materials for reducing heat transfer and improving energy efficiency in buildings located in tropical climates such as Ebonyi State. The study recommends that homeowners, architects, and builders prioritize roofing materials with low thermal conductivity and incorporate proper roof insulation and ventilation in building designs.

Keywords: Comparative evaluation, heat absorption, thermal performance, roofing materials and Abakaliki Building Materials Market.

INTRODUCTION

Roofing materials are essential components of building structures, serving as protective barriers against environmental conditions such as rainfall, solar radiation, wind, and temperature fluctuations. Beyond their structural and aesthetic functions, roofing materials significantly influence indoor thermal comfort, energy efficiency, and environmental sustainability. In tropical regions such as Nigeria, where solar radiation is intense and ambient temperatures are high throughout most of the year, the heat absorption characteristics of roofing materials become a critical factor in building design and occupant comfort (Ogedengbe and Akinbile, 2021).

Heat absorption refers to the capacity of a material to absorb solar energy and convert it into heat. Roofing materials with high heat absorption tend to increase indoor temperatures, thereby creating discomfort and increasing reliance on artificial cooling systems such as fans and air conditioners. This can lead to elevated energy consumption, higher utility costs, and increased environmental impacts due to greater carbon emissions (Adebayo, 2020). Conversely, roofing materials with low heat absorption or better thermal insulation properties can help maintain cooler indoor environments and improve energy conservation.

In Ebonyi State, Nigeria, rapid urbanization and increasing demand for affordable housing have led to widespread use of various roofing materials, including polycarbonate roofing sheets, galvanized steel roofing sheets, fiber cement roofing sheets, and corrugated roofing sheets. These materials differ in composition, thickness, thermal conductivity, reflectivity, and durability, all of which influence their thermal performance. For example, galvanized steel roofing sheets are widely used because of their affordability and durability, but they often exhibit high thermal conductivity, resulting in greater heat transfer into buildings (Asan, 2021). Fiber cement sheets, on the other hand, are known for better thermal resistance, while polycarbonate sheets provide lightweight alternatives with moderate heat absorption characteristics. Corrugated roofing sheets remain popular due to their versatility and structural strength.

Abakaliki Building Materials Market in Ebonyi State is a major commercial center for roofing products, offering diverse options to builders and homeowners. However, many consumers select roofing materials based primarily on cost, durability, or appearance, with limited consideration for thermal performance (Nwokporo et al., 2025). This often results in the adoption of roofing materials that contribute to excessive indoor heat, discomfort, and increased cooling costs.

Previous studies have shown that building envelope materials significantly affect indoor thermal environments. According to Taiwo et al. (2023), inappropriate roofing material selection is a major contributor to indoor overheating in tropical residential buildings. Similarly, Omoniyi and Arosoye (2020) observed that cement-based roofing systems generally provide better thermal comfort than metallic alternatives in hot climates. Despite these findings, localized studies focusing specifically on roofing materials sold in Abakaliki are limited.

Therefore, this research seeks to investigate the heat absorption performance of selected roofing materials sold at Abakaliki Building Materials Market, Ebonyi State. The findings provide empirical data to guide homeowners, architects, builders, and policymakers in making informed decisions regarding suitable roofing materials for tropical climates.

MATERIALS AND METHODS

Research Design

The study adopted an experimental research design to comparatively evaluate the heat absorption and thermal performance of four roofing materials: polycarbonate, galvanized steel, fiber cement and corrugated roofing sheets. Four identical miniature test chambers were constructed and roofed separately with the selected materials. Reduced-scale roof test rigs are an established approach for experimentally evaluating roof temperature and thermal performance (Michels et al., 2021; Kothari, 2019).

Study Area

The study was conducted in Abakaliki, Ebonyi State, Nigeria. The selected roofing materials were obtained from the Abakaliki Building Materials Market. The test chambers were installed in an open area with adequate exposure to solar radiation and without obstruction from buildings or trees.

Materials and Equipment

The materials and equipment used included:

- i. Polycarbonate roofing sheet
- ii. Galvanized steel roofing sheet
- iii. Fiber cement roofing sheet
- iv. Corrugated roofing sheet
- v. Plywood for chamber construction
- vi. Roofing screws and nails
- vii. Measuring tape
- viii. Spirit level and angle gauge
- ix. Digital thermometer
- x. Reference thermometer for calibration
- xi. Digital clock
- xii. Data-recording sheets

Roof temperature and indoor temperature measurements are appropriate indicators for comparative roof thermal-performance studies.

Construction and Dimensions of Test Chambers

Four identical test chambers were constructed from timber frames covered with plywood. Each chamber measured approximately $1.00\text{ m} \times 1.00\text{ m} \times 1.00\text{ m}$, giving a floor area of 1.00 m^2 and an internal volume of approximately 1.00 m^3 .

The four chambers were constructed using the same wall, floor and framing materials. Only the roofing material was varied. The chambers were labelled as follows:

- i. Chamber A – Polycarbonate
- ii. Chamber B – Galvanized steel
- iii. Chamber C – Fiber cement
- iv. Chamber D – Corrugated sheet

Each roof extended approximately 0.10 m beyond the chamber walls on all sides to provide similar shading and rain protection. The roofing sheets were firmly fixed to identical timber roof frames.

The use of identical reduced-scale chambers minimizes variations arising from chamber geometry and allows the effect of roofing material to be compared under similar conditions.

Roofing Material Thickness and Specifications

The roofing samples were selected from commercially available materials in the Abakaliki Building Materials Market. Their thicknesses were measured before installation as indicated below.

Table 2.1: Roofing Material Thickness and Specifications

Roofing Material	Approximate Thickness	Specification
Polycarbonate	3.0 mm	Lightweight translucent roofing sheet
Galvanized steel	0.50 mm	Corrugated galvanized steel sheet
Fiber cement	6 mm	Corrugated fiber-cement sheet
Corrugated sheet	0.50 mm	Corrugated metallic roofing sheet

The actual thickness measured for each sample was recorded and used in the final experimental report. Material thickness is relevant because thermal behaviour depends partly on the physical and thermophysical characteristics of the roofing system.

Roof Orientation and Slope

All four chambers were positioned on the same level surface and oriented in the same north–south direction to provide comparable exposure to solar radiation. A uniform roof slope of approximately 15° was used for all chambers.

A spirit level and angle gauge were used to verify that the roof slopes were approximately equal. Equal orientation and slope were maintained throughout the experiment. Similar field studies have controlled model orientation and roof configuration when investigating roofing thermal performance.

Ventilation Conditions

The chambers were naturally ventilated through identical openings. Each chamber had one ventilation opening of approximately 0.10 m × 0.10 m, positioned at the upper portion of the wall.

The openings were identical in size and position for all chambers and remained unchanged during measurements. No mechanical fan was used. This ensured that differences in indoor temperature were not caused by unequal ventilation.

Measurement Locations

Temperature measurements were taken at three standardized locations:

Roof surface: Sensor fixed to the exposed upper surface near the centre of each roofing sheet.

Indoor air: Sensor positioned approximately 0.50 m above the floor and at the centre of each chamber, without touching the roof, wall or floor.

Ambient air: Sensor placed approximately 1.5 m above ground level in a shaded, naturally ventilated position near the chambers.

The same relative sensor positions were maintained throughout the experiment. Similar roof studies have simultaneously measured roof, internal and ambient temperatures to evaluate thermal behaviour (Asan, 2021).

Instruments and Accuracy

Digital thermometer temperature sensor with a measurement range of approximately 0 – 100°C and accuracy of about ± 0.5°C were used.

The same type of sensor was used at corresponding measurement points to minimize systematic differences

between measurements. The manufacturer's stated accuracy was recorded in the experimental logbook.

Calibration Procedure

Before data collection, all temperature sensors were checked against a calibrated reference thermometer.

An ice-water bath was used for an approximately 0°C check, while a second comparison was made at normal ambient temperature. Sensors were allowed to stabilize before readings were compared. Any sensor showing an unacceptable deviation was adjusted where possible or replaced.

The calibration check was repeated at the end of the experiment to identify possible measurement drift.

Measurement Interval

Temperature readings were taken at one-hour intervals from 8:00 a.m. to 3:00 p.m. each experimental day.

At each interval, the following were recorded:

- i. Ambient temperature
- ii. Polycarbonate roof surface and indoor temperatures
- iii. Galvanized steel roof surface and indoor temperatures
- iv. Fiber cement roof surface and indoor temperatures
- v. Corrugated roof surface and indoor temperatures

The sensors were allowed to stabilize before each reading was recorded.

Duration of Experiment

The experiment was conducted for five suitable sunny days. Measurements were taken daily from 8:00 a.m. to 3:00 p.m., providing repeated observations of the thermal behaviour of each roofing material.

Where prolonged rainfall or abnormal weather occurred, the affected day was identified and an additional suitable day was used where necessary. Longer-duration roof studies have also been used to account for changing environmental conditions in thermal-performance investigations.

Method of Data Collection

Primary data were collected through direct temperature measurements using digital thermometers and infrared sensors. Data were recorded in structured observation tables for analysis.

The heat absorbed by each roofing material was estimated using the heat transfer equation:

$$Q = mc\Delta T \quad 1$$

Where:

Q = Heat absorbed (J)

M = Mass of roofing material (Kg)

C = Specific heat capacity (J/KgK)

ΔT = Change in temperature (°C or K) (Fourier, 1822).

Thermal conductivity was evaluated using Fourier's law:

$$Q = KA \frac{(T_1 - T_2)}{d} \quad 2$$

Where:

Q = Heat transfer rate (W)

K = Thermal conductivity (W/mk)

A = Area of roofing material (m²)

T₁ - T₂ = Temperature difference (°C)

d = Thickness of roofing material (m)

The average temperature for each roofing material was calculated using:

$$\bar{X} = \frac{\sum X}{N} \quad 3$$

Where:

$\bar{X}$ = Mean temperature

$\sum X$ = Sum of temperature values

N = Number of observations

Method of Data Analysis

Collected data were analyzed using descriptive statistical methods such as mean temperature values and percentage heat absorption. Comparative tables and bar charts were used to present temperature variations and thermal performance of the roofing materials.

RESULTS AND DISCUSSION

Results

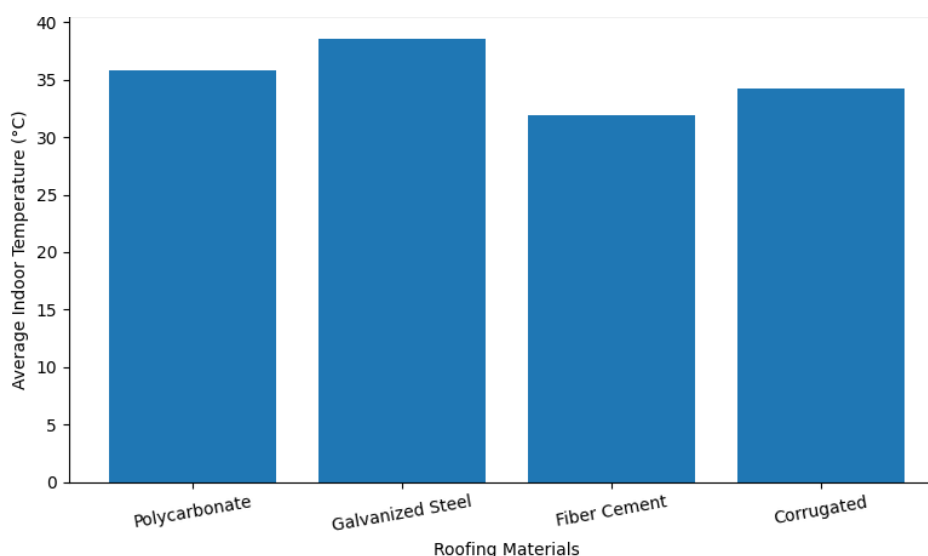
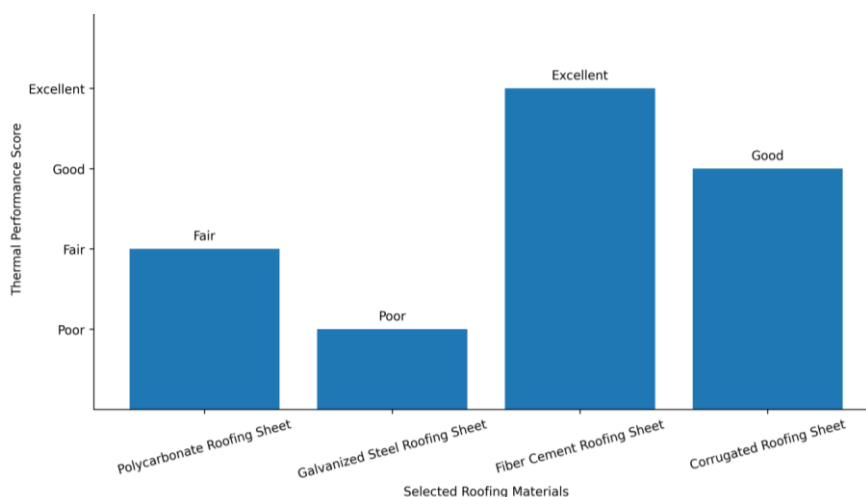
The results obtained from the average indoor temperature recorded under selected roofing materials were found in Table 3.1 and Figure 3.1 below while comparative evaluation of thermal performance of roofing materials were recorded in Table 3.2 and Figure 3.2 respectively.

Table 3.1: Average Indoor Temperature Recorded Under Selected Roofing Materials

S/N	Roofing Material	Average Indoor Temperature (°C)	Heat Absorption Level
1	Polycarbonate Roofing Sheet	35.8	High
2	Galvanized Steel Roofing Sheet	38.6	Very High
3	Fiber Cement Roofing Sheet	31.9	Low
4	Corrugated Roofing Sheet	34.2	Moderate

Table 3.2: Comparative Evaluation of Thermal Performance of Roofing Materials

S/N	Roofing Material	Thermal Conductivity	Thermal Performance
1	Polycarbonate Roofing Sheet	Moderate	Fair
2	Galvanized Steel Roofing Sheet	High	Poor
3	Fiber Cement Roofing Sheet	Low	Excellent
4	Corrugated Roofing Sheet	Moderate	Good


Fig. 3.1: Bar Chart of Average Indoor Temperature Recorded Under Selected Roofing Materials

Fig. 3.2: Bar Chart of Comparative Evaluation of Thermal Performance of Roofing Materials

DISCUSSION OF RESULTS

Table 3.1 presents the average indoor temperatures recorded under the four selected roofing materials. Galvanized steel roofing sheets recorded the highest average indoor temperature of 38.6°C, followed by polycarbonate roofing sheets with 35.8°C, corrugated roofing sheets with 34.2°C, and fiber cement roofing sheets with the lowest value of 31.9°C.

The relatively high temperature recorded under galvanized steel can be attributed to the high thermal conductivity of steel, which allows absorbed solar heat to be transferred rapidly through the roofing material. In contrast, the lower temperature recorded under fiber cement suggests greater resistance to heat transfer and better thermal insulation. This observation agrees with Almeida et al. (2018), who reported differences in the thermal behaviour of metallic and fiber-cement roofing materials.

Figure 3.1 graphically illustrates the results presented in Table 3.1. The height of each bar represents the average indoor temperature recorded beneath each roofing material. The galvanized steel bar is the highest, confirming its 38.6°C temperature, while the fiber cement bar is the lowest, corresponding to 31.9°C.

The difference of 6.7°C between galvanized steel and fiber cement demonstrates a considerable variation in indoor thermal conditions. Therefore, buildings roofed with materials having lower heat-transfer characteristics may experience better thermal comfort during periods of high solar radiation.

Table 3.2 compares the overall thermal performance of the four roofing materials. Polycarbonate roofing sheets were classified as Fair, galvanized steel as Poor, fiber cement as Excellent, and corrugated roofing sheets as Good.

The classification corresponds generally with the temperature results in Table 3.1. Fiber cement, which recorded the lowest indoor temperature, was rated excellent, whereas galvanized steel, which recorded the highest temperature, was rated poor. Michels et al. (2021) similarly reported improved thermal resistance in fiber-cement roofing systems.

Note: Because Table 3.2 gives qualitative ratings rather than measured numerical thermal-performance values, the chart uses an illustrative ranking scale: Poor = 1, Fair = 2, Good = 3, Excellent = 4.

Figure 3.2 presents the thermal-performance ratings graphically. Fiber cement roofing sheets have the highest rating (Excellent), followed by corrugated roofing sheets (Good), polycarbonate roofing sheets (Fair), and galvanized steel roofing sheets (Poor).

The figure therefore provides a clear visual comparison of the thermal performance of the selected materials. The results suggest that fiber cement is the most suitable of the four materials for reducing heat transfer into buildings, while galvanized steel may require additional insulation or ventilation to improve its thermal performance.

The findings also agree with Taiwo (2023), who reported that roofing materials with improved thermal resistance contribute to better thermal comfort and reduced energy consumption in tropical climates.

CONCLUSION

Based on the results obtained, the selected roofing materials exhibited different levels of heat absorption and thermal performance. Galvanized steel roofing sheets recorded the highest indoor temperature and therefore showed the poorest thermal performance, while fiber cement roofing sheets recorded the lowest indoor temperature and showed the best thermal performance.

The study therefore concludes that fiber cement roofing sheets are more suitable for buildings where reduction of heat gain and improvement of indoor thermal comfort are important. The selection of thermally efficient roofing materials can also contribute to reduced dependence on mechanical cooling systems and improved building energy efficiency (Taiwo, 2023).

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