TIMBOU-AFRICA PUBLICATION INTERNATIONAL JOURNAL FEBRUARY, 2025 EDITIONS.

INTERNATIONAL JOURNAL OF BUILT ENVIRONMENT AND EARTH SCIENCE
VOL. 7 NO. 4 E-ISSN 3027-1606 P-ISSN 3027-0049

ANALYSIS OF STRATEGIES FOR ATTAINMENT OF ADAPTIVE THERMAL COMFORT IN BUILDINGS IN NIGERIA: REVIEW OF METHODS

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DOI: https://doi.org/10.70382/tijbees.v07i4.025

ABSTRACT

Acceptable thermal comfort conditions in buildings are necessary to ensure health and wellbeing of occupants, enhance productivity of workers, et cetera. Passive or active strategies can be utilized to achieve these acceptable thermal comfort conditions. Passive methods are encouraged in buildings because they are considered to be environmentally friendly. This research aimed to review passive methods and materials used in

Introduction

A third of global energy is consumed by buildings for heating, cooling and lighting (Wu, Jin, Liu and Li, 2024). In Nigeria, the Building Energy Efficiency Guide-BEEG (2017) puts the annual energy consumption of some office buildings at 249 KWh/m^2/year of which 87% is used for cooling and 12% for lighting. Using electrical apparatuses for Heating, Ventilating and Air-conditioning (HVAC) in offices and other structures, increase the carbon footprint of buildings (Danja, Wang, Mukhta, Inuwa, and Anvar, 2020). Because of global warming concerns, scientists are heeding the call to shift their focus from using fossil fuel for electricity generation to environmentally friendly systems (Danja, Wang, Mukhta, Inuwa, and Anvar, 2020). These concerns have forced a return to passive strategies in buildings. While the world is just starting to embrace passive strategies in buildings, Nigerian traditional (a blend of cultural and environmental influences on architecture) and vernacular (a blend of traditional and contemporary

traditional, vernacular and modern-day architectures to provide thermal comfort conditions for occupants of indoor spaces in tropical Nigeria. The author systematically reviewed and analysed 29 papers using statistical tables and chart. The findings showed that natural ventilation is the most used passive strategy. The study also indicated that traditional and vernacular buildings depend on the thermal properties of indigenous building materials and climate responsive strategies to provide acceptable thermal conditions for occupants. Modern-day buildings need shading, insulation and covering from the intense solar radiation in the study area compared to traditional or vernacular buildings. Despite their aesthetical appeals, the study concluded that modern-day building cannot be relied upon to provide thermal comfort for building occupants. If modern-day building materials must be used, then appropriate passive strategies must also be deployed to ensure the provision of acceptable thermal comfort conditions for building occupant in the tropics.

Keywords: Adaptive comfort, Building, Passive Strategies, Thermal, Tropics.

influences on architecture) structures have been judged to be highly friendly to the environment (Mobolade and Pourvahidi, 2020). The acceptance of environmental friendly principles stemmed from the fact that frequent Power disruptions (Peter, 2010; Danja, Wang, Mukhta, Inuwa, and Anvar, 2020) have placed the comfort needs of occupants solely at the mercy of the building envelopes and their design proficiencies (Akande, 2010; Akanmu *et al.,* 2021).

Given Nigeria's closeness to the equator, the sunrise and sunset daily rhythm do not differ significantly throughout the year. The Tropical region is characterized by intense sunshine, temperatures that could hover around 25°C to 44°C and Relative Humidity (RH) between 50% to 90% (Akanmu, Nunayon and Eboson, 2021). These conditions encourage rapid evaporation; high afternoon temperatures, cold and dry harmattan in some parts of the country (Mobolade and Pourvahidi, 2020). Amidst these conditions, Nigerian traditional and vernacular builders have developed methods that are used with locally available building materials to deliver building outcomes that are people specific and climate responsive to achieve thermal comfort. These builders understood that air flow is crucial (Okeke et al., 2011 as cited in Mba, *et al.*, 2022) hence, openings are made to enhance

good air velocity which increases heat transfer between the body and the air through convection (Delft, 2004). Strategic building orientation are also used to ensure the wellbeing of occupants (Mba, Sam-amobi and Okeke, 2022). In addition, the builders use readily available materials with good thermal properties to ensure comfortable indoor conditions (Sa'ad, 1991). These research took a review of these methods and building materials used in some traditional, vernacular and modern-day architecture in Nigeria.

Only few researches have been conducted on passive thermal comfort methods in Nigeria. Ogbonna and Harris (2008) carried out a study to collect empirical thermal comfort data from Jos city in tropical Nigeria. Using digital tools, the authors measured the temperature, humidity, CO_2 and lighting levels of spaces. The research also used questionnaires to collect data on the occupants' sensations of thermal comfort. The results indicated a number of conditions in which occupants in naturally ventilated buildings can be comfortable. In another study, Oluwafemi et al, in 2009 conducted a research to determine the indoor thermal comfort conditions for occupants of residential buildings in hot-dry climate of Nigeria. The field study findings revealed that thermal sensation votes exceeded acceptable conditions set by ASHRAE, yet about 80% of occupants found the thermal conditions favourable. Yet still, Seun et al (2022) conducted research to find appropriate mitigation techniques to address the issue of urban heat island in Lagos, Nigeria. To attain thermal comfort environment in the region, the research recommended that urban planning strategies that include embracing green initiatives such as planting of trees should be adopted. No study has been done to analyse and review passive methods that innovatively use building materials from traditional, vernacular and modern-day architectures to provide adaptive thermal comfort conditions in indoor spaces in tropical Nigeria.

Modern-day building materials have thermal properties that make them differ from materials used in vernacular and traditional buildings (Sa'ad, 1991). A review of the literature was done to analyse these methods and identify the most used strategies in some traditional, vernacular and modern-day buildings to attain adaptive thermal comfort. The outcome of

this study would help builders make the right choices on which strategy or building materials to use when designing buildings that are climate responsive in tropical Nigeria.

THERMAL CHARACTERISTIC OF THE BUILDING ENVELOPE

When solar radiation strikes the building envelope, it raises the temperature of the elements. Through conduction, convection and radiation the heat is transported to the interior (Babiarz and Szyma´ nski, 2020; Hu, Sun, Liang, Zhou and Yin, 2023). When solar radiation strikes the natural ground, floor and other surfaces around the building, radiative heat is generated by the surroundings. Portion of the radiative heat gets transported to the building envelope which eventually ends up in the interior (Babiarz and Szyma´ nski, 2020; Hu, Sun, Liang, Zhou and Yin, 2023). On the other hand, if direct solar radiation enters through glazed windows or other openings they heat up surfaces (Babiarz and Szyma´ nski, 2020; Hu, Sun, Liang, Zhou and Yin, 2023). To achieve equilibrium temperature, there is continuous exchange of heat among building element surfaces, furniture surfaces, air and humans- since heat flows from region of high concentration to that of low concentration (Babiarz and Szyma´ nski, 2020).

Many traditional and vernacular building materials like grass, mud brick, bamboo, palm frond, et cetera are poor conductors of heat while modern-day materials like aluminium sheets, concrete, glass, ceramic tiles et cetera are good conductors (Mobolade and Pourvahidi, 2020). Using indigenous building materials provide insulation against outdoor heat or cold while using modern-day building material allows for exchange of heat. Ensuring good thermal environment is a function of employing good passive strategy that utilizes effective use of building materials.

METHODOLOGY

This study identified passive strategies and building materials used in both traditional, vernacular and modern-day architectures. Using google scholar, the author identified 29 papers that carried out studies using passive strategies in traditional, vernacular and modern-day buildings. The selected papers were read and analysed. the findings are summarized and presented in tables and figures below.

FINDINGS AND DISCUSSION

The chart in figure 1 shows that ventilation is the most research passive strategy in thermal comfort studies among the papers reviewed. This is largely because ventilation is an important aspect in adaptive thermal comfort attainment in naturally ventilated buildings especially in tropical climates (ASHRAE, 55). Though Wall thickness (thermal mass) and orientation are the least research strategy, they are important in regulating the heat gain and loss by the building envelope.

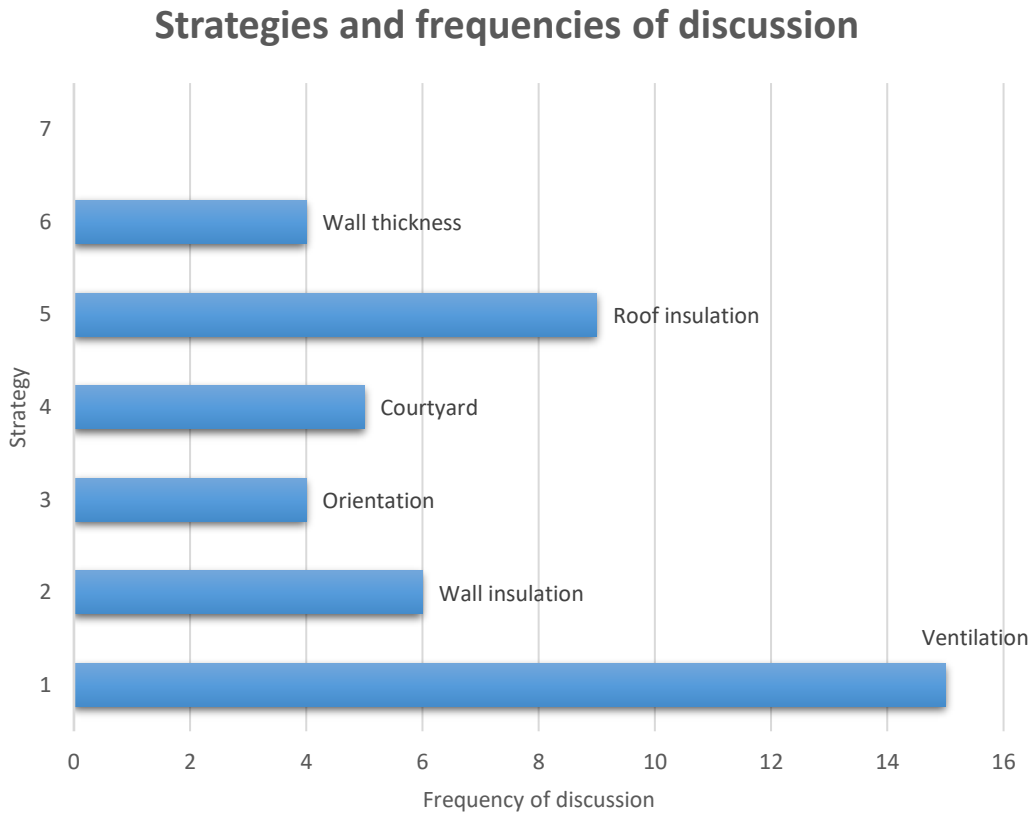

Figure 1: Strategies and frequency of discussion in some selected papers
Source: Author (2025)

Given the continuous heat exchange between the indoor and outdoor spaces through the building envelope (Babiarz and Szyma´ nski, 2020), this study analysed the two most affected building components (roofs and walls) that are directly exposed to the climatic elements. The finding from the analysis is presented in figure two below. Traditional and Vernacular building materials were analysed together and tagged indigenous building materials.

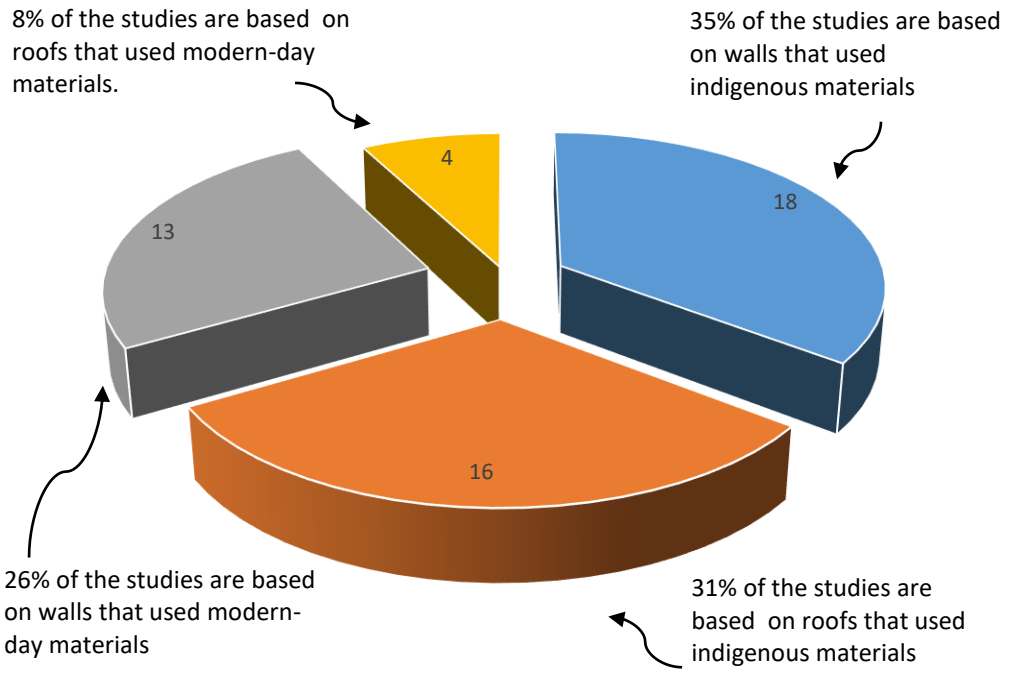

Figure 2: Analysis of building materials use in some selected studies.
Source: Author, 2025

The result of the findings indicates that 66% of the studies were based on roofs and walls that used indigenous building materials. The analysis further indicates that the high use of indigenous building materials for passive strategies is because of their potentials to ensure climate specific responses to the thermal needs of occupants in the region (Mobolade and Pourvahidi, 2020). Modern-day buildings depend on electrical equipment for attainment of acceptable indoor conditions for occupants.

The table below also shows the summary of the building materials used, passive strategies employed and major findings in 29 selected papers. Many of the findings indicated that good utilization of building materials and passive strategy would enhance thermal comfort for occupants of indoor spaces in the tropics. Some examples of the findings include research by Sa'ad (1991) where he found out that mud brick walls provided better thermal comfort due to higher thermal mass and insulation. Aliyu *et al.* (2022) also found out that Green roofs and earth walls provided effective passive cooling in tropical climates. Summaries of other findings are shown in table one below;

Table 1: Summary of building materials, passive strategies and findings in some studies

Sourec: Author (2025)

Author	Title	Building material used	Passive strategy	Finding
Akingbade - 2003	Indoor Thermal Environment and Comfort Conditions in the Temperate Dry Zone of Nigeria: Case Study of Zaria	Not stated	Natural ventilation	Individuals expressed comfort in the temperature range of 24°C to 28°C, with mean indoor temperature at 26.3°C and relative humidity at 30.5%
Oluwafemi et al - 2009	Indoor Thermal Comfort for Residential Buildings in Hot-Dry Climate of Nigeria	Not stated	Natural Ventilation	Thermal sensation votes exceeded stated conditions set by ASHRAE, yet 80% of occupants found the thermal conditions comfortable.
Olotuah - 2010	Thermal Comfort in Residential Buildings in Hot-Dry Climate of Nigeria	Mud bricks, concrete blocks	Natural ventilation, shading	Mud brick walls provided better thermal comfort due to higher thermal mass and insulation.
Ogunsote et al. - 2010	Thermal Comfort in Residential Buildings in Hot Humid Climates	Concrete, sandcrete blocks	Natural ventilation, shading	Natural ventilation and shading significantly improve thermal comfort in buildings.
Akande - 2010	Passive Design Strategies for Residential Buildings in a Hot Dry Climate in Nigeria	Not stated	Proper orientation, natural ventilation, selection of building materials	Identified passive design strategies to minimize energy use for cooling, improve occupant comfort, and enhance low-energy architecture in Nigeria.
Olanipekun - 2014	Thermal Comfort and Occupant Behaviour in a Naturally Ventilated Hostel in Warm-Humid Climate of Ile-Ife, Nigeria: Field Study	Not stated	Natural ventilation	Measured variables fell below comfort range recommended by ASHRAE and ISO standards; respondents were comfortable, preferring cooler environments and more air movement
Danfulani et al.- 2015	Passive Cooling Strategies for Thermal Comfort in Tropical Nigeria	Laterite, sandcrete blocks	Courtyard design, roof insulation	Courtyard designs improved airflow, while insulated roofs reduced indoor temperatures.
Isah - 2015	An Assessment of Thermal Comfort in Hot and Dry Season: A Case Study of 4 Theaters at Bayero University Kano	Not stated	Natural Ventilation	Thermal conditions exceeded ASHRAE standards, but 80% of respondents still found them acceptable. Unacceptable conditions were attributed to building design and construction materials.
Adekunle et al. - 2015	Thermal Comfort in Residential Buildings	Concrete, sandcrete blocks	Natural ventilation, shading	Natural ventilation significantly improves thermal comfort in hot climates.
Okeke et al. - 2015	Passive Design Strategies for Thermal Comfort in Tropical Climates	Orientation, vegetation, cross-ventilation	Mud bricks, thatch roofs	Proper orientation and use of local materials enhance thermal comfort in tropical climates.
Akinbami et al. - 2017	Traditional vs Modern Building Materials	Natural ventilation, courtyards	Laterite, concrete	Traditional materials like laterite provide better thermal comfort.
Sadiq et al. - 2018	Evaluation of Thermal Comfort in Traditional Hausa Buildings	Mud, thatch, timber	Thick walls, small windows	Traditional Hausa buildings with thick walls maintained lower indoor temperatures.
Olanrewaju et al. - 2018	Passive Cooling Strategies in Tropical Climates	Mud bricks, thatch roofing	Thermal mass, cross-ventilation	Mud bricks and thatch roofing reduce indoor temperatures effectively.
Asoegwu et al. - 2018	Evaluation of Thermal Comfort in Traditional Nigerian Buildings	Laterite, mud, thatch	Courtyard design, thick walls	Traditional courtyard designs and thick walls provide better thermal regulation.
Ojo et al. - 2019	Impact of Shading Devices on Thermal Comfort	Concrete, glass	Shading devices, overhangs	Shading devices reduce indoor temperatures by 2-3°C during peak hours.

Author not stated - 2019	Thermal Comfort in Igbo Traditional Homes, Nigeria	Indigenous materials	Traditional design elements	Users accept wider temperature variations in buildings with limited or no air-conditioning; traditional buildings in Nigeria provide thermal comfort.
Jimoh et al. - 2020	Impact of Building Materials on Indoor Thermal Comfort in Northern Nigeria	Concrete, clay tiles	Reflective roofing, thermal mass	Reflective roofing materials significantly reduced heat gain in buildings.
Fagbenle et al. - 2020	Evaluation of Building Materials for Comfort	Aluminium roofing, fiberglass	Reflective roofing, insulation	Reflective roofing materials reduce heat gain by up to 30%.
Akaninu et al. - 2020	Impact of Building Materials on Indoor Thermal Comfort in Nigeria	Concrete, aluminium roofing	Insulation, reflective roofs	Reflective roofing materials and insulation reduce indoor temperatures significantly.
Ojo et al. - 2021	Thermal Performance of Low-Cost Housing in Tropical Climates	Cement blocks, corrugated iron	Cross-ventilation, shading devices	Cross-ventilation and shading devices improved thermal comfort in low-cost housing.
Okonkwo et al. - 2021	Thermal Performance of Low-Cost Housing	Bamboo, compressed earth blocks	Green roofs, natural ventilation	Green roofs and natural ventilation improve comfort.
Oladokun et al. 2021	Thermal Performance of Low-Cost Housing in Tropical Climates	Bamboo, compressed earth blocks	Passive cooling, green roofs	Green roofs and passive cooling strategies improve thermal comfort.
Olumide et al - 2021	Optimization of Building Envelopes Using Indigenous Materials to Achieve Thermal Comfort and Affordable Housing in Abuja, Nigeria	Indigenous materials with low u-values	Replacing conventional building envelope materials with indigenous materials	Using indigenous materials for floor, external walls, and roof could reduce operative temperature by 8%, increase thermal comfort, and reduce CO_2 emissions, cooling loads, and construction costs
Aliyu et al. - 2022	Sustainable Building Design for Thermal Comfort in Northern Nigeria	Earth, bamboo, thatch	Passive cooling, green roofs	Green roofs and earth walls provided effective passive cooling in tropical climates.
Emeka et al. - 2022	An Assessment of Orientation on Effective Natural Ventilation for Thermal Comfort in Primary School Classrooms in Enugu City, Nigeria	Not stated	Building orientation for natural ventilation	Orientation of classroom buildings with respect to wind direction significantly affects natural ventilation efficiency, influencing thermal comfort conditions.
Nwadike et al. - 2022	Adaptation of Vernacular Architecture for Thermal Comfort in Nigeria	Wood, mud, thatch	High ceilings, large windows	Vernacular architectural features like high ceilings and large windows enhance airflow and comfort.
Moses et al. - 2022	Natural Ventilation Architectural Design for Passive Cooling in a Multi-Purpose Building Development in Calabar City, Nigeria	Not stated	Central courtyard design to enhance natural ventilation and passive cooling	Proposed a "breathing building" design with wind-driven and buoyancy features as a substitute for conventional cross-ventilation methods, enhancing indoor airflow and thermal comfort.
Francis et al. - 2023	Influence of Building Attributes on Thermal Comfort in Naturally Ventilated Hospital Wards in the Hot-Humid Tropics of Southeast Nigeria	Not stated	Natural ventilation	Neutral temperature ranges from 26.2 °C to 29.9 °C; thermal conditions did not meet ASHRAE Standard 55; building orientation, window size and placement influenced thermal comfort.
Praise et al. - 2023	Exploring the Use of Indigenous Building Materials to Achieve Thermal Comfort in a Hot, Humid Climate: The Case of South Eastern Nigeria	Timber, bamboo, thatch, earth-based construction.	Use of indigenous materials	Indigenous materials possess inherent thermal properties, effective moisture management, and natural heat dissipation, contributing to thermal comfort.

Table two below indicated how passive strategies were utilised with indigenous and contemporary building materials by some studies to attain adaptive thermal comforts.

Table 2: Analysis of strategy usage based on building material type.

Source: Author (2025)

Passive strategy utilization	Need for Orientation	Need for Ventilation	Need for shading	Courtyard use for comfort	Roof's insulation potential	Wall's insulation potential
Rate of utilization with Indigenous building materials	2	7	1	6	11	5
Rate of utilization with Contemporary building materials	2	8	9	2	5	None was utilized

Orientation is important to both traditional, vernacular and modern-day building occupants as it can help to shield structures from strong wind and high solar radiation exposures. This is in agreement with traditional and contemporary practices where buildings are oriented to provide shade from the harsh afternoon sun in the tropics for occupants (Sa'ad, 1991). Many modern-day building materials are good conductors of heat (Babiarz and Szyma´ nski, 2020) hence, they need shading from the intense solar radiation of the tropics as shown in table two above. On the other hand, traditional and vernacular building materials need little shading as their poor heat conductive properties make them suitable for use in the tropical region as shown by many studies in table one. Courtyard is a passive design strategy utilized by many traditional and vernacular builders as a method to regulate heat in buildings. The finding indicates the high utilization of courtyards in traditional building. This finding aligned with conclusions from a study by Moses *et al,* (2022) which portrayed courtyards as "breathing building" which are designed with "wind-driven and buoyancy features as a

substitute for conventional cross-ventilation methods, enhancing indoor airflow and thermal comfort". The high proportionate rate of utilizations of the insulation properties of indigenous building materials for roofs and walls as indicated in table two shows how these materials, if properly used, can lead to thermal comfort conditions. This finding also aligned with many other research outcomes including Olumide *et al.* (2021) which showed that using indigenous materials for floor, external walls, and roof could reduce operative temperature by 8%, increase thermal comfort, and reduce CO_2 emissions and cooling loads.

CONCLUSION AND RECOMMENDATIONS

This research shows that using indigenous building materials with passive design strategies that are well adapted and suited for the Nigeria tropical climate can provide acceptable thermal comfort conditions in traditional, vernacular and modern-day buildings. Despite this superior performances of traditional and vernacular building materials for thermal comfort conditions attainment, modern-day building materials are preferred and used in many buildings today. No doubt, these contemporary building materials have good strength properties, high durability, better flexibility, good fire safety quality ratings, high aesthetic appeal, et cetera but their poor thermal performances in hot climate made them unsuitable for use in tropical regions (Akande, 2010; Danja, Wang, Mukhta, Inuwa and Anvar, 2020). If they must be used in the tropics, then appropriate passive strategies should be employed to enhance their thermal properties. Deploying good passive strategies would help to ensure thermal comfort for building users; reduce the carbon footprint of buildings and ensure that the adaptive thermal needs of building occupants are catered for even during frequent power outages in Nigeria (Peter, 2010; Danja, Wang, Mukhta, Inuwa and Anvar, 2020).

This paper recommends that more studies should be carried out to provide findings that can be applied to enhance the strength quality, durability, better fire performance and increase the aesthetics appeals of indigenous

building strategies and materials to ensure that they are accepted by builders and home owners in these contemporary times.

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