British Journal of Environmental Sciences
Vol.11, No.1, pp.,11-33, 2023
Print ISSN: 2055-0219(Print)
Online ISSN: 2055-0227(online)

The Impact of Rainfall on The Conservation of Traditional Nigerian Heritage Buildings: A Case Study of the Museum of Traditional Nigerian Architecture (MOTNA), Jos

Iliya Mela
Department of Architecture, School of Design, Shanghai Jiao Tong University
Yongkang Cao
Department of Architecture, School of Design, Shanghai Jiao Tong University

DOI: https://doi.org/10.37745/bjes.2013/vol11n11133 Published: 19st January 2023

Citation: Mela I. and Cao Y. (2023) The Impact of Rainfall on The Conservation of Traditional Nigerian Heritage Buildings: A Case Study of the Museum of Traditional Nigerian Architecture (MOTNA), Jos, *British Journal of Environmental Sciences*, Vol.11, No.1, pp.,11-33

ABSTRACT: *Advancements in building construction technology and the advent of foreign materials that came with Nigeria's colonial and post-colonial periods led to the mass abandonment of traditional buildings for a "contemporary" option. The need to preserve the nation's architectural heritage led to the establishment of the Museum of Traditional Architecture (MOTNA). Within the museum are life-size replicas of various traditional buildings across the country. Studies, observations, and documentaries reveal how the longevity and functionality of indigenous Nigerian buildings have been altered by weather elements such as precipitation and relative humidity. This study investigates the impact rainfall has on the conservation of traditional heritage buildings over time. Four buildings that together represent the bioclimatic zones in Nigeria were selected through purposeful sampling. Heritage buildings were investigated through the case study/observation method. The studies revealed that all heritage buildings were significantly affected by the effects of rainfall due to their design morphology and material usage. The investigation concluded that the conservation of Nigerian traditional heritage buildings can be unusually challenging. This is because most local building materials are susceptible to the effects of rainfall and require frequent replacement, which might be against conservation laws.*

KEYWORDS: rainfall, heritage buildings, conservation, traditional architecture, preservation

INTRODUCTION

The traditional architecture of any society reflects its historical significance, sociocultural values, craftsmanship, and religious beliefs, as well as the aesthetic appreciation of its people. Preserving the heritage buildings of a people is as critical as preserving their values. Building conservation can be referred to as any measure taken towards maintaining the physical outlook of a building without altering its original fabric or introducing a foreign element to it (Bernard, 2003). Prior to the colonial era, most Nigerians lived in traditional houses made of locally sourced building materials. The design and layout of these local architectures were partly an expression of cultural values and a response to bioclimatic factors. Nowadays, with the introduction of modern building technologies and foreign building materials such as steel, concrete, aluminum, and glass, a significant number of Nigerians are now opting for contemporary houses made of unsustainable foreign materials. Hence, the need to not only preserve the nation's heritage but also innovate the "old" as a sustainable substitute for the modern becomes of paramount importance.

Numerous studies have revealed the role of conserving a nation's heritage buildings in the development of its history, architectural identity, and cultural values (Bernard, 2003; Osasona, 2017; Adeyemi, 2008; and Al-Sakkaf, A., Zayed, T., & Bagchi, A., 2020). Other authors have also studied the reasons responsible for the negligence of Nigerian traditional architecture and the factors influencing its longevity and have discovered issues like poor maintenance, obsolescence, exposure to dampness, erosion, inadequate funding, poor legislation, poor physical planning, and vandalism at the top of the list (Akinbamijo & Alakinde, 2013; Iliyasu, 2014; Bomi-Daniels, 2022) It should be noted, however, that all existing studies, except Eneh & Ati (2009), did not go beyond listing these factors. This study, Eneh & Ati (2009), focused on the influence of rainfall on Hausa traditional architecture and did not examine the traditional house forms of other regions. Using individual buildings as case studies to analyze how rainfall affects the various traditional buildings will revalidate previous findings. This will also explain how these deteriorations occur and suggest ways that design and innovation can help improve the longevity and usability of traditional buildings.

Research Objective

- To ascertain the various building components ruined by the effect of rainfall and why
- To analyze the local building materials used in heritage buildings that are prone to the negative effect of rain and moisture
- To highlight design character or material selections that allow for the impact of rainfall

Scope of Study

The study only looked at indigenous Nigerian buildings on the grounds of MOTNA in Jos, Plateau State, Nigeria. Among these buildings, four were selected for the study based on their geographical origin. These buildings represent the traditional architecture of Nigeria's four climatic zones, namely: tropical monsoon, tropical savannah, hot desert climate, and hot semi-arid climate. For the sake of this study, the hot desert climate and the hot semi-arid climate will be considered a single climatic zone because of their physical and cultural similarities. Case studies will be conducted on two buildings from these regions. MOTNA was chosen because of its comprehensive representation of the nation's traditional architecture, with over twenty life-size replicas of typical traditional Nigerian buildings.

RESEARCH METHODOLOGY

This study largely relies on case studies of selected buildings as the main research approach. Data was collected from physical observation of building components such as the foundation, exterior walls, and roof. Other features like building layouts, cultural influence, prior conversion interventions, and the original climatic context were noted. Museum staff and occupants of some heritage buildings were interviewed to better comprehend the situation on the ground. Buildings were selected based on the climatic zones they represent and the degree of their deterioration. Secondary data were obtained by reviewing relevant literature.

LITERATURE REVIEW

Climatic Profile of Nigeria

Nigeria has four distinct climate zones: a tropical monsoon climate in the south, a tropical savannah climate in most of the central regions, and a Sahelian hot and semi-arid climate in the north. This results in a gradient of decreasing precipitation amounts from south to north. In the southern regions, rainfall events are frequent during the rainy season, which lasts from March to October. Annual rainfall amounts are usually above 2,000 mm, and in the Niger Delta, they can exceed 4,000 mm and more. (World Bank Climate Change Knowledge Portal, n.d.)

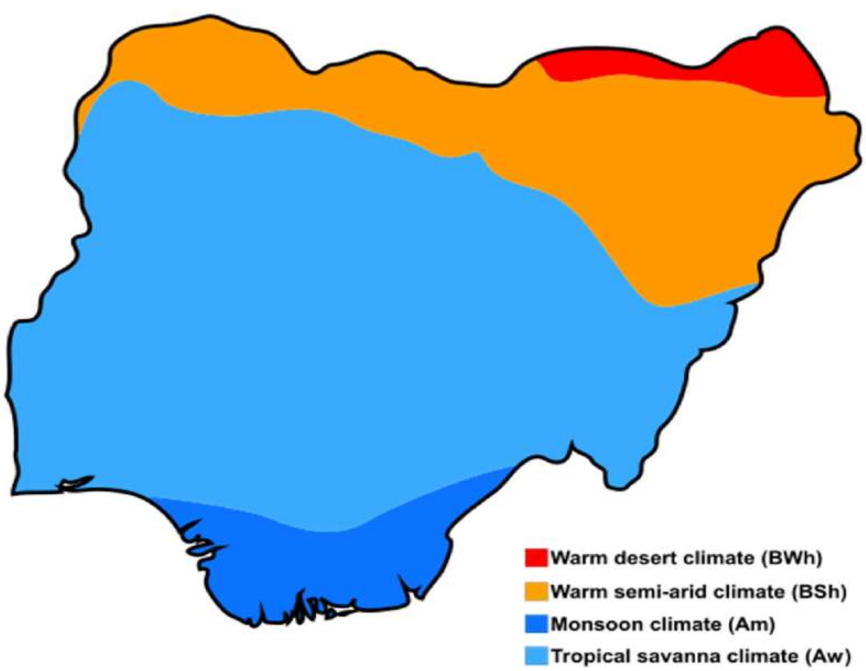

Figure 1: Koppen-Geiger Classifications. (Source: Scientific Data, 2020)

Central regions are characterized by a single rainy season (April to September) and a dry season (December to March). During the dry season, the Harmattan wind blows from the Sahara. There is a short dry season along the coast, with the majority of the rain falling between March and October. It is possible to receive 1200 millimetres of rainfall every year. A typical rainy season in the north is from June to September, with a rainfall range of 500 mm to 750 mm. Other than that, it's a hot and dry climate. Northern regions experience varying rainfall regimes throughout the year, resulting in flooding and droughts (World Bank Climate Change Knowledge Portal, n.d.)

It can be said that Nigeria has the greatest variation in temperature between its coastal areas and its interior, as well as between its plateau and its lowlands. It is generally observed that the mean annual temperature on the plateau varies between 21 °C and 27 °C, whereas it is generally higher than 27 °C in the interior lowlands. A lower mean value is found in the interior lowlands in comparison to coastal fringes in the coastal regions. In most areas of the country, there are consistently high seasonal mean temperatures, and there is more variation among the seasons than between the diurnal and seasonal variations. From the coast to inland areas, the temperature varies little during the dry season. As with rainfall in Nigeria, relative humidity decreases from the south to the north, with an annual mean of 88% around Lagos (World Bank Climate Change Knowledge Portal, n.d.)

During December, January, and April, Nigeria has average monthly temperatures between 24 °C and 30 °C. An average of 1,165.0 mm of precipitation falls each year. It is common to experience rain throughout the year in Nigeria, with the majority of rainfall occurring between April and October and the least occurring between November and March (World Bank Climate Change Knowledge Portal, n.d.)

Rainfall in Jos

Located at an elevation of 1263.05 meters (4143.86 feet) above sea level, Jos has a Tropical wet and dry or savanna climate (Classification: Aw). The district's yearly temperature is 28.41 ºC (83.14 ºF) and it is -1.05% lower than Nigeria's averages. Jos typically receives about 155.51 millimeters (6.12 inches) of precipitation and has 181.54 rainy days (49.74% of the time) annually. (Global Historical Weather and Climate Data, n.d.)

Figure 2: Recent mean temperatures and precipitation for Jos (Source: Global Historical Weather and Climate Data, n.d.)

Heritage Building Conservation

Heritage Buildings

As defined by UNESCO (2007), heritage can be divided into two major categories: natural heritage and cultural heritage. Natural heritage can be defined as features of the natural environment (physical and biological structures) that have been universally recognized as having scientific, conservational, or aesthetic value. These consist of habitats for vulnerable animal and plant species. The concept of "cultural heritage" refers to structures, monuments, clusters of buildings, archaeological sites, and landscapes that have historical, scientific, aesthetic, anthropological, or cultural significance. UNESCO (2007) recognized traditional buildings and sites of ancient civilizations as "heritage buildings."

Conservation

A definition from the Oxford Advanced Learner's Dictionary (n.d.) suggests that the process of preservation and repair of archaeological, historical, and cultural places and artifacts can be referred to as "conservation." Architectural conservation can be referred to as the preservation of valuable architectural structures or architectural assets. (Taher Tolou Del et al., 2020)

Vol.11, No.1, pp.,11-33, 2023
Print ISSN: 2055-0219(Print)
Online ISSN: 2055-0227(online)

The goal of conservation should always be to achieve the highest possible results by taking the least impactful actions. Whenever possible, the action should be reversible and should not have an adverse effect on future interventions (Bernard, 2003). This is because the aim of conservation is to maintain buildings without the need for foreign intervention, keeping them in their original state. Bernard (Bernard, 2003) advocates that the first step in the conservation of a heritage site is its listing as a heritage building or site, followed by regular documentation and inspection, and finally, appropriate planning and implementation at the city level.

Conservation exercises typically require a multidisciplinary team, ranging from structural engineers, art historians, archeologists, architects, and other professionals. Each of these professionals plays a unique role in the conservation process and tends to focus on one aspect over another. According to Bernard (2003), order and effectiveness can be achieved by clearly defining the goals of the project and identifying the values associated with the building, site, or object involved. Based on the collective interpretation of the value of the object, the significance of the exercise can be determined. These sets of values are grouped into three categories: "emotional" values, "cultural" values, and "use" values. Several factors contribute to emotional values, including wonder, identity, continuity, respect, and veneration, both symbolic and spiritual. Among the cultural values are documentary, historical, archaeological, and age values, as well as aesthetic and architectural values, as well as ecological, technological, and scientific values. A building's "use values" are determined by factors such as its functionality, economic relevance, social relevance, educational value, and political importance.

Ethics of Conservation

The following are the standard procedures for any conservation exercise, as suggested by Bernard (2003):

1. It is necessary to determine and record the current condition of the building prior to any intervention.
2. Artifacts must be handled with care, and their conditions must not be altered or recorded incorrectly.
3. To preserve the originality of the object, it is imperative to adopt a strategy that has the least impact on its originality.
4. Conservation interventions must acknowledge the aesthetic, historic, physical, and sociocultural value of the object. It is imperative to respect the significance of the object and what it represents.
5. Intervention exercises should be thoroughly documented; the technologies employed, materials used, and considerations taken should be adequately detailed.

Traditional Nigerian Heritage Buildings

Western Nigeria

Two of the most prominent architectural styles in the west are those of the Yoruba and Benin people. Culturally, historically, and even linguistically, these two ethnic groups share much in common. There is a lot of similarity between their building layouts, and there are similarities in the way they express courtyards and use impluvium. In addition, there are similarities in the common materials used to build them.

Typically, Yoruba traditional compounds fall into two categories: the first is a compound built around a central hall or corridor to house several polygamous families tied together by senior males from the father's side. As a burial ground and the resting place of the family's ancestors, the courtyard serves as an integral part of Yoruba culture. A rectangular or square courtyard allows sleeping spaces, storage spaces, and kitchens to be arranged around it (Rikko & Gwatau, 2011; Adeyemi, 2008, & Moughtin, 1988). The central spaces are also used to host family activities such as meetings, moonlight tales, and celebrations. With the growth of the family, more courtyards are constructed, forming a series of hollow, rectangular compounds that are connected in a linear fashion. Often, the lean-to roof that covers the surrounding spaces extends into a veranda, which serves as a circulation space and a buffer zone between the interior and exterior environments. In terms of layout and arrangement, Benin architecture is similar to Yoruba architecture, except for its unique form of material expression, wall renderings, and symbolism.

Eastern Nigeria

In the east, architecture is largely characterized by the local architecture of the Igbo people. Traditional Igbo architecture also makes use of the courtyard system as part of its design. The layout consists of huts arranged in an enclosure, which serves as a courtyard. Unlike most regions, the Igbos have more than one house form. These consist of circular, oval, square, and rectangular forms. An arrangement of huts in a compound is determined by a particular pattern, and different huts serve different purposes within the compound. Usually referred to as "obi", a special hut is usually reserved for the head of the family; it is often situated in the middle of the family compound with its entrance facing the main entrance. In addition to housing the head of the family, the obi also serves as a place for decision-making, and as the soul of the family as well. (Okoye & Ukanwa, 2019)

Middle Belt

The Middle Belt is a highly diverse region. As a result, it is the only region in Nigeria without a single dominant ethnic group. Traditional architectures found in this region include those of the Tiv and Igala people of Benue state; the Tarok, Beroms, and Ngas of Plateau state; the Baju and Jabba of Kaduna state; and the Jukun and Kuteps of Taraba state. A majority of the houses in the middle belt are curvilinear in shape, and the layout of the compounds varies from tribe to tribe. Cultural beliefs, societal structure, and material availability also influence the construction methods, materials, and ornamentation of buildings. Most of these housing layouts follow a concentric or radial pattern. (Rikko & Gwatau, 2011). As explained by Rikko & Gwatau (2011), these house forms were influenced by external factors (such as western house forms from colonial eras), resulting in rectilinear variations. The oval huts are grouped around a central open space, while the rectilinear buildings are usually constructed separately or arranged to form a rectangular courtyard.

There is no doubt that Jabba architecture is one of the most fascinating forms of traditional architecture. It is characterized by its oval plans and suspended, mezzanine-like floors. Although the walls and floors of these spaces are clearly defined, they are seamlessly integrated. Its concentric roof allows for the irregular height of the mud structure and, at the same time, covers a wider area. It is one of the few local Nigerian architectural styles in which the roof is not directly connected to the interior. Contrary to Hausa architecture, the mud roof is covered by a conical thatch roof with an overhang for rain protection. This system of double roofing also helps in creating a more constant interior climate, especially during hot seasons.

In contrast to most ethnic groups, the layout of the Tiv huts is largely dispersed. Ideally, it is categorized based on genealogical hierarchy: Men are assigned a substantial portion of space within the larger compound to form their own households. These huts are characterized by an exceedingly high-pitched roof made of wooden sticks as rafters covered by a very thick layer of thatch. The height of their roofs is usually twice as high as their mud walls, if not more. Like many other examples of traditional architecture, the head of the compound’s residence is usually situated in the middle of the compound in a building called the "Ate" (Moughtin, 1988).

Northern Nigeria

Even though northern Nigerian architecture is often characterized by Hausa architecture, the style is far from universal. As with other regions of the country, the North is a region with a heterogeneous culture. While it is true that the Hausa-Fulani are the largest ethnicity in northern Nigeria, there are many other tribes with distinct architecture, especially in the eastern part of the region, where tribes include Tangale, Waja of Gombe State, Kanuri of Borno State, Bade of Yobe, and Katsina State, all of which are in the eastern part of the region.

A look at the architecture of the Bachama people reveals its similarities to many other northeastern tribes. Its compounds are described as having perimeter walls made of plaited grass. The first hut upon entering the compound is used for receptions and public functions. Grown-up males are assigned rooms near the entrance to the compound. There are separate sleeping and cooking areas for women and children within the compound, with each wife having an exclusive area for sleeping and cooking. These spaces were demarcated by walls made of woven thatch and supported by wooden poles (Saad, H. T., 1991). Zones are defined by the function assigned to the space and the category of users. The reason why men's rooms are typically closer to the entrance is because, culturally, the male is considered the defender of the household. Therefore, no intruder can enter a family compound without encountering the household's head.

Hausa architecture is distinguished by its extensive use of earth as a building material for both walls and roofs, with rectangular or square compound layouts and minimalistic geometric house forms (usually cuboidal). Its walls are made of thick earthen ovoidal blocks (called tubali), which are vertically stacked and bound by a mud paste. This same mud paste is used as a wall finish, protecting the traditional masonry unit against the elements of the weather. Hausa architecture also makes use of a courtyard system with rooms bordering the open courtyard, which often serves as a family gathering space.

Effect of Rainfall on Local building Materials

There are many advantages to using traditional building materials: they are environmentally friendly, can be sourced locally, are relatively inexpensive, and often possess favorable thermal properties. They are, however, susceptible to the effects of weather elements such as rain, humidity, and temperature (Okpalanozie & Adetunji, 2021). Among the most common building materials found in Nigeria are clay (earth), bamboo, wood, thatch, straw, and stone.

Earth

Earth is the most prevalent local building material in Nigerian traditional architecture. Its usage cuts across all climatic regions of Nigeria. As with any construction method, its methods of application and construction differ across regions, with each strategy depending on soil type, climatic conditions, cultural beliefs, and skillsets (Oshike, 2015). The aesthetic orientation of a people can also influence the application of earth as a building material across regions. Some common earth construction techniques include wattle and daub, adobe (earth brick), adobe (tubali), cob (direct layering), and compressed earth blocks (CSB) (Oshike, 2015). Despite the superior thermal properties and other benefits of earthen structures, they are at risk of disintegration if not bonded with a powerful binder such as cement. Earthen walls are subject to the following problems:

Disintegration due to erosion or direct exposure to rainfall (Oshike, 2015; Ndububa & Mukaddas, 2016): Earthen walls are largely made of sand, and sand has a low coercive strength, especially when in contact with water. Earthen walls lose their strength as they become exposed to water through rainfall erosion or other means. As a result, there is a risk of wall collapse and faulty foundations. As a result, mud buildings must undergo routine maintenance on a regular basis.

Loss of strength due to dampness: Moisture content absorbed by earthen walls through capillary action can affect the strength of the building (Oshike, 2015; Ndububa & Mukaddas, 2016). Sand is hydrophobic by nature, meaning it can take in and retain water. If an earthen wall is exposed to moisture over a prolonged period, the wall mass becomes saturated with moisture, weakening the bond between sand particles. Natural elements such as straws are often used as stabilizers. This material, however, can decay with prolonged moisture retention, compromising the structural integrity of the building. A study by Ndububa and Mukaddas (2016) on mud house failures in Bauchi, Nigeria, compared the percentage of roofing leakage between straw roofs, straw-stabilized mud roofs, and galvanized corrugated iron sheets and determined that houses with mud roofs experienced the greatest amount of leakage at 500%. It is for this reason that mud roofs and other traditional roofing options have been replaced with galvanized corrugated iron sheets imported from abroad.

Wood

The use of wood as a construction material is also prevalent in Nigeria. In traditional buildings, its application varies from region to region and from culture to culture. In some riverine areas of Nigeria, wood is used for foundations (as stilts), flooring, walls, and roofs. In the Middlebelt and the north, wood is mostly used as part of the roofing structure, as wall frames, and as pillars. These woods vary from traditional timber to bamboo to palm wood from coconut trees. Although some of these woods are durable and termite-resistant, they are susceptible to decay if exposed to dampness for an extended period. (Udoudoh, F.P., Bassey, L.E.2021)

Thatch

Another popular local building material among Nigerian ethnic groups is thatch, or straw. Straws, which are usually the stalks and byproducts of cereal crops, are gathered and dried shortly after harvest seasons, then bundled and used as roofing, fencing, and walling materials. Straws are woven or tied in a linear pattern and wrapped around the often conically shaped wood roof framing (Udoudoh, F.P., Bassey, L.E., 2021). Like other organic building materials, straws are basically dried dead plants and are prone to decomposition and the activities of microorganisms when exposed to constant rainfall or moisture. Thatched roofs are also prone to leaks during prolonged periods of rainfall.

CASE STUDIES

Brief History of MOTNA

On January 1, 1973, Gen. Yakubu Gowon, the then Nigerian Head of State, laid the foundation stone of the Museum of Traditional Nigerian Architecture (MOTNA). Professor Zbigniew Dmochoski, a Polish architect, was responsible for the design and construction. Until the completion of the project in 1983, he served as chief architect. During the 1983 Pan African Conference held in Nigeria, an elaborate event opened the project to the public in December 1983. Several people from different parts of Africa attended this event over the course of several days.

Zaria Mosque

This edifice is a life-size replica of the Friday Mosque (known as the Massalaci Juma'a), originally located in Zaria. The original mosque was built between the 1830s and 1840s by a renowned master builder known as Babban Gwani. The mosque is divided into three sections: the Sharia court, prayer section, and ablution chambers. A grid of columns separates the prayer hall into six sections (Moughtin 1988). The foundation is made up of quarried stone that was raised above ground level to protect the earthen wall from erosion.

The walls are constructed of egg-shaped, sunbaked earthen bricks called tubali, which are stacked together and bonded together with mud to form a monolithic structure. These walls have a very thick base, which tapers as it slopes up to allow the wall to support its own weight. As a rule of thumb in tubali construction, the higher the height of the wall, the thicker the base. Tubalis are made by mixing mud excavated from pits with straws, which serve as stabilizers.

Present Condition:

As it stands now, the Friday Mosque has largely crumbled to the ground. The effect of continuous contact with water can be seen in various elements of the building. Due to the building's flat roof and lack of overhangs, its earthen roof, walls, and foundation are constantly subjected to the elements of weather, such as rainfall and humidity. It appears that the walls have absorbed a considerable amount of rainfall and water content to the point where plants, grasses, and mold are flourishing on them. This is possible because within its walls are plants and seeds that can grow if exposed to the right conditions over a prolonged period.

Figure 3: Ruins of Zaria Friday Mosque

Figure 4: Oval earth bricks (Tubali)

Alongside the straws used as stabilizers are other dead plants and animals' organic matter that, when exposed to constant moisture, begins to decay. This process of decay dematerializes organic matter, creating voids within the walls that can affect the structural integrity of the building. The mosque is reinforced by palm-wood beams called azara. Though this wood is quite durable in the sense that it is termite-resistant, it is prone to decay when exposed to moisture content. With constant exposure to rainfall and atmospheric moisture, most azara reinforcements have not only decayed but have given way to the heavy weight of the roof they once supported.

A cross section of a tubali wall as seen in figure 4 indicates that the mud bricks weren't the most affected. Instead, it was the earth that was used to bind the tubalis together. These had a large proportion of sand in them as opposed to the tubalis, which were of a finer particle and were properly compressed. It can be concluded that rainfall had a more significant effect on the mortar than on the brick.

The Bight of Benin

The Bight of Benin is a life-size replica of a typical Benin palace. The building is made up of a rectangular courtyard and an impluvium in the center which defines the shape of the building. A veranda surrounds the courtyard and serves as a circulation space and access to individual spaces. The building was made of earthen walls covered with a fine layer of mud in both the interior and exterior spaces. The perimeter walls are rendered with grooving which resembles the corrugations of a metal sheet. Aside from the aesthetic function of these decorations, the grooving helps keep rainwater off the wall. Currently, the building is used as a restaurant. It is one of the very few and probably the first to be adaptively reused.

Present condition.

Even though the building has undergone several conservation interventions, especially in its interior spaces, the effect of rain and moisture has affected some elements of the building, some of which are beyond redemption.

Roof: In this case, the roof was the most impacted by the effect of rainfall. Initially, the roof was made of wooden slates, as was the case in a typical Benin palace. Over time, the effect of rainfall, which led to moisture exposure, began to deteriorate the roof. Upon the deterioration of the wooden slates, they were replaced with yet another local material, thatch. However, inconsistency in routine roof replacement led to the imminent decay of the straw due to prolonged exposure to rainfall. At present, the roof of the building looks nothing like its original design. This is because the local roofing material has been replaced with a combination of corrugated zinc and aluminum roofing sheets.

Figure 5: deteriorated thatch and bamboo poles sitting on aluminum and zinc corrugated sheets

Walls: The lower part of the walls has been impacted by rainfall due to an inadequate roof overhang, which was unable to keep the wall dry in wet weather**.** Until a drainage system was made around the perimeter of the building as part of a conservation intervention, it was constantly affected by erosion and the absorption of surface runoff from its foundation upwards. This is evident from the gradual disintegration of the wall rendering and the growth of mold at the base of the wall.

Figure 6: Entrance to Benin palace walls

Figure 7: Mold on the base of exterior

Irigwe Compound

The Irigwe compound falls under the architecture of the tropical savannah climatic region (AW). The compound comprises round and circular-edged square huts with stone foundations, earthen walls, and a thatch roof. The compound follows the typical pattern of architecture in this region. Relief decorations can be seen on the exterior of the circular walls. Bamboo poles are used for roof framing. They are tied together by ropes woven from the bark of certain local plants.

Condition in 2010

The photos below show the state of the buildings in the compound as of December 2020. At that point, all the roofs in the compound were leaking. Polythene sheets had to be introduced as a conservative measure to prevent any further damage to the thatch. The renderings on the wall had multiple cracks, and the effects of water and wind erosion can be seen on it. Part of the foundation was already exposed because of erosion.

Figure 8: Irigwe hut in 2020 **Figure 9: Irigwe hut conservation in 2020**

Present Condition:

As of today, only one hut remains in the compound and its walls are in a dilapidated state. A significant portion of the clay mortar has been washed off while the other part is filled with cracks. The traditional bamboo and thatch roof has been replaced with corrugated metal roofing sheets and traditional modern timber. The foundation is fully exposed, so much so that the foundation now sits at a height of about 450mm above present ground level.

Figure 10: sole standing Irigwe hut in 2022 **Figure 11: Dilapidated hut 2022**

Kano Wall

The wall in Kano, like the mosque in Zaria, is originally from a warm semi-arid climate (BSh). It is a replica of the great walls of Kano, built in the tenth century. It was constructed using the tubali system of construction. For structural support, azara (palm wood) was used. Like the Zaria Friday Mosque, the Great Wall of Kano faces a similar challenge, with rain constantly washing off its mud protective layer and subsequently the tubalis. Its lack of covering and waterproof quality makes it quite susceptible to rainfall. As a result, a significant part of it has been eroded by rainfall and wind. A conservative intervention in the form of a canopy was carried out to preserve its remains but its deterioration continues.

Figure 12: section of great wall of Kano with stacks of tubali under a canopy as conservation intervention

Figure 13: side view of Kano wall **Figure 14: Exposed palm wood on earth wall**

The case studies showed that for all heritage buildings, one or more of the deteriorated components had been compromised by the effects of rain. While one might argue that the Zaria Mosque, the Kano Wall, and the Bight of Benin are not originally of the tropical savannah climate zone and that might have affected their longevity as they were built for a relatively different climate, the case is no different, as studies of traditional architecture in those regions have highlighted dampness, rainfall, and erosion as some of the factors affecting the longevity of local traditional buildings. Also, the building materials used across all regions of the country are largely the same.

Heritage Building Components Affected by The Effect of Rainfall

Building components	Zaria Friday Mosque	Bight of Benin	Irigwe Compound	The great Kano Wall
Foundation	✓		✓	
Wall	✓	✓	✓	✓
Wall finish and decoration	✓	✓	✓	✓
Roofing members	✓	✓	✓	✓
Roof covering	✓	✓	✓	✓

Table 1: Heritage Building Components Affected by The Effect of Rainfall

Materials Used on Heritage Building Components

It can also be noticed that the most prevalent materials are earth, wood, and straw or thatch. The walls and roofs of all the heritage buildings studied were made up of one or a combination of any three of these local materials. All these materials are prone to decay and deterioration when exposed to rainfall and dampness.

	Zaria Friday Mosque	Bight of Benin	Irigwe Compound	Kano Wall
Foundation	Stone	Stone	Stone	Stone
Wall	Earth (tubali with straw)	earth	earth	Earth (tubali with straw)
Wall finish and decoration	earth	earth	earth	earth
Roofing members	Palm wood	Bamboo	Bamboo	Palm wood
Roof covering	earth	Wooden slates, Thatch	Thatch	Earth

Table 2: Materials used on heritage building components

British Journal of Environmental Sciences
Vol.11, No.1, pp.,11-33, 2023
Print ISSN: 2055-0219(Print)
Online ISSN: 2055-0227(online)

Design Analysis

Heritage Building	Observations
Zaria Friday Mosque	• Presence of organic material (which is prone to decay) on the walling unit • The tubali (walling units) are not water- or moisture-proof. • Palm trees (Azara) are naturally prone to absorb moisture, except when treated, which can lead to their decay. • Inadequate foundation drainage, which exposes the foundation and foundation to erosion, leading to structural compromise. • Tubules have varying structural integrity due to the lack of a standard ratio of material composition. • Clay wall finishes are prone to absorbing water and moisture. • Absence of protective cover from rain and other elements of weather • The earthen roof was not treated to repel water.
Bight of Benin	• The roof overhangs are not wide enough to protect the entire wall. • Wooden roof slates are neither waterproof nor treated, making them susceptible to moisture absorption, insect invasion, and microbial inoculation. • Clay wall finishes are prone to absorbing water and moisture.
Irigwe Compound	• Thatch as a roofing material is not durable, especially when exposed to rain for a prolonged period. • Absence of foundation drainage • Wall renderings and finishes are not waterproof. • Short roof overhangs • The material composition of the wall unit is heterogeneous.
Kano Wall	• Presence of organic material (which is prone to decay) on the walling unit • Tubali (walling units) are not water or moisture proof. • Palm trees (Azara) are naturally prone to absorb moisture, except when treated, which can lead to their decay. • Inadequate foundation drainage, which exposes the foundation and foundation to erosion, leading to structural compromise. • Due to the lack of a standard mix ratio of material composition, tubalis have variable structural integrity. • Clay wall finishes are prone to absorbing water and moisture. • Absence of protective cover from rain and other elements of weather

Table 3: Design analysis

Overall State of Heritage Building Components

Foundations were the least affected by the effects of rainfall. This is largely because the foundations were made of stone pebbles and quarried stones, which are highly durable materials and water-resistant. Roofing members and roof coverings, which are largely

@ECRTD-UK: https://www.eajournals.org/
Publication of the European Centre for Research Training and Development -UK

made of earth and/or thatch, are the most deteriorated. This is because the roof is the component that protects the entire structure from climatic factors and is the most exposed to rain. This constant contact with rainfall can lead to seepage, saturation of materials with moisture, and the disintegration of local materials over time. The physical condition of building components is graded on a point scale, with "poor" indicating the least favorable possible condition and "excellent" indicating a very favorable condition. The description of the ratings as coined by U.S. Department of Transportation (2018) can be seen below.

Building components	Zaria Friday Mosque	Bight of Benin	Irigwe Compound	Kano Wall
Foundation	adequate	adequate	Marginal	adequate
Wall	Poor	adequate	Poor	Poor
Wall finish and decoration	Poor	adequate	Poor	Poor
Roofing members	Poor	Poor	Poor	Poor
Roof covering	Poor	Poor	Poor	Poor

Table 4: Overall state of heritage building components

Condition assessment rubric:

Condition	Description
Poor	Highly damaged or in need of immediate repair: well past useful life
Marginal	Components are deteriorated and need to be replaced
Adequate	Partly deteriorated but is still within its functional limit
Good	Components are in good shape with little defects and signs and deterioration but still within useful limit
Excellent	Great condition and good as new. No sign of wear and tear

Table 5: Condition assessment rubric (Source: U.S. Department of Transportation, 2018)

It can be observed that the Zaria Friday Mosque, Irigwe compound, and Kano wall have the most deteriorated components. They have all their components in a poor state except for the stone foundations. The overall functional state of these buildings is poor, as they have significantly deteriorated and are well past their useful lives.

CONCLUSION

Following a careful examination of the subject, it is possible to conclude that the effect of rainfall is a common challenge affecting Nigerian traditional architecture regardless of climatic or geopolitical zone. This impact can be seen in the buildings' lifespan, functionality, cultural value, and aesthetic appreciation.

The current state of Nigerian traditional heritage buildings points out the fact that local Nigerian building materials and design decisions were not meant to last long without regular maintenance or restorative interventions. This is evident in the relative temporality of the materials in the face of weather conditions such as rainfall. It can also be seen in design decisions, such as shorter overhangs, shallow foundations, and exposed earthen walls. It therefore becomes much more difficult to preserve architecture that was meant to be renewed or restored on an annual basis. This is because "conservation" refers to preserving building elements and materials in their original condition with minimal physical alteration. This therefore calls for an urgent need for innovation of local traditional building materials and a rethinking of traditional building design methodologies such that buildings can withstand weather elements for centuries (as seen in Europe) and are able to function accordingly without demanding frequent routine maintenance.

Despite the adverse effects of rainfall on building materials, an adequate maintenance culture and conservation intervention has been lacking in many of these heritage buildings. The need for the management of MOTNA to increase the frequency of maintenance and devise alternatives to keeping heritage buildings dry will have a tremendous positive impact on the longevity of the buildings.

REFERNCES

Adeyemi, E. A. (2008). Meaning And Relevance In Nigerian Traditional Architecture: The Dialectics Of Growth And Change. *Covenant University Press*, *1*(21), 8–17. https://www.semanticscholar.org/paper/Meaning-And-Relevance-In-Nigerian-Traditional-The-Ekundayo/c60014776c16d2770848217b0882cb675c30c713

Akinbamijo, A. O., & Alakinde, A. M. (2013). Nigerian Heritage and Conservation Landuses - Challenges and Promises. *International Journal of Education and Research*, *1*(6). http://www.ijern.com/

Al-Sakkaf, A., Zayed, T., & Bagchi, A. (2020). A Review of Definition and Classification of Heritage Buildings and Framework for their Evaluation. *D International Conference on New Horizons in Green Civil Engineering (NHICE-02)*. https://www.researchgate.net/publication/341160581_A_Review_of_Definition_and_Classification_of_Heritage_Buildings_and_Framework_for_their_Evaluation?enrichId=rgreq-1a45eb460d20c0371e105f90fb0d6238-

XXX&enrichSource=Y292ZXJQYWdlOzM0MTE2MDU4MTtBUzo5NDExNTM3MjE1MzY1MTNAMTYwMTM5OTk0MTg0NQ%3D%3D&el=1_x_2&_esc=publicationCoverPdf

Bernard, F. (2003). *Conservation of Historic Buildings, Third Edition* (3rd ed.). Architectural Press.

Bomi-Daniels, F. A. (2022). Assessing the state (physical and functional) of the heritage buildings in Lagos State. *African Journal of History and Culture*, *14*(1), 1BCC2BF69325. https://doi.org/10.5897/AJHC2022.0549

Eneh, A. E. O., & Ati, O. F. (2009). The influence of rainfall on Hausa Traditional Architecture. *Research Journal of Applied Sciences, Engineering and Technology*, *2*(8), 695–702. https://www.cabdirect.org/abstracts/20113061737.html

Figure 1: New and improved KÃ¶ppen-Geiger classifications. | Scientific Data. (2020, August 17). Nature. https://www.nature.com/articles/sdata2018214/figures/1?error=cookies_not_supported&code=155a2195-75b3-4c75-b968-3b4c3f3a292f

Global Historical Weather and Climate Data. (n.d.). Weather and Climate. Retrieved December 24, 2022, from https://tcktcktck.org/

Iliyasu, I. isah. (2014). Challenges Of Preservation of Cultural Landscapes In Traditional Cities: Case Study Of Kano Ancient City. *Conference: International Council for Reseach and Innovation in Building and Construction*. https://www.researchgate.net/publication/273462667_Challenges_Of_Preservation_Of_Cultural_Landscapes_In_Traditional_Cities_Case_Study_Of_Kano_Ancient_City

Joel, A., Olukunle. (2015). Conservation Of Traditional Earth Building In Nigeria: Case Study Of Origbo In Ife North, Osun State. *International Journal of African Society Cultures and Traditions*, *2*(2), 56–67. http://www.eajournals.org/

Ndububa, E., & Mukaddas, A. M. (2016). Mud House Failures and Mitigation Options in Bauchi, Northeast Nigeria. *FUOYE Journal of Engineering and Technology*, *1*(1). https://doi.org/10.46792/fuoyejet.v1i1.11

Okoye, C. B., & Ukanwa, O. E. (2019). Igbo Traditional Architecture: A Symbol of Igbo Cultural Identity. *International Journal of Scientific & Engineering Research*, *10*(11). https://www.ijser.org/

Okpalanozie, O. E., & Adetunji, O. S. (2021). Architectural Heritage Conservation in Nigeria: The Need for Innovative Techniques. *Heritage*, *4*(3), 2124–2139. https://doi.org/10.3390/heritage4030120

Osasona, C. (2017). Nigerian architectural conservation: *A case for grass-roots engagement for renewal*. *International Journal of Heritage Architecture: Studies, Repairs and Maintence*, *1*(4), 713–729. https://doi.org/10.2495/ha-v1-n4-713-729

Oshike, E. E. (2015). Building With Earth in Nigeria: A Review Of The Past And Present Efforts To Enhance Future Housing Developments. *International Journal of Science, Environment and Technology*, *4*(1), 646–660. https://www.ijset.net/

Oxford Advanced Learner's Dictionary. (n.d.). *conservation noun - Definition, pictures, pronunciation, and usage notes | Oxford Advanced Learner's Dictionary at OxfordLearnersDictionaries.com*. https://www.oxfordlearnersdictionaries.com/us/definition/english/conservation

Quetext.com. (2022, September 23). *Original Writing, Made Easy With*. Quetext. https://www.quetext.com/login?callback=/account/subscription

Rikko, L. S., & Gwatau, D. (2011). The Nigerian architecture: The trend in housing development. *Journal of Geography and Regional Planning*, *4*(5), 273–278. https://doi.org/10.5897/jgrp.9000143

Solomon Zi, W., & Hyacinth M, D. (2020). Climate Change, Rainfall Trends and Variability in Jos Plateau. *Journal of Applied Sciences*, *20*(2), 76–82. https://doi.org/10.3923/jas.2020.76.82

Taher Tolou Del, M. S., Saleh Sedghpour, B., & Kamali Tabrizi, S. (2020). The semantic conservation of architectural heritage: the missing values. *Heritage Science*, *8*(1). https://doi.org/10.1186/s40494-020-00416-w

Tambiyi, G. Y., & Anuye, S. P. (2019). Factors Militating the Development of Jos Museum and its Role in the Preservation of Historical and Religious Heritage. *Journal of Multidisciplinary Studies*, *1*(2), 259–270. http://hdl.handle.net/123456789/3280

Udoudoh, F. P., & Bassey, L. E. (2021). Traditional Building Materials in Housing Construction: Usage and Maintenance Strategy. *PM World Journal*, *10*(4), 2330–4480. http://www.pmworldjournal.com/

Umar, S. B., & Said, I. (2018). Conservation Challenges of Heritage Building Reuse in Nigeria: A review of decision-making models. *Asian Journal of Environment-Behaviour Studies*, *4*(12), 16–36. https://doi.org/10.21834/aje-bs.v4i12.336

UNESCO. (2007). Convention Concerning the Protection of the World Cultural and Natural Heritage Paris, 16 November 1972. *Standard-Setting at UNESCO*, 135–148. https://doi.org/10.1163/ej.9789004164543.1-760.22

U.S. Department of Transportation. (2018). TAM Facility Performance Measure Reporting Guidebook: Condition Assessment Calculation. In *Federal Transit*

Administration. Retrieved December 10, 2022, from https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-guidance/asset-management/60361/tam-facility-performance-measure-reporting-guidebook-v1-2.pdf

World Bank Climate Change Knowledge Portal. (n.d.). https://climateknowledgeportal.worldbank.org/country/nigeria/climate-data-historical