



Indoor Space Optimization through Sustainable Roof Design in Residential Buildings in Rivers State, Nigeria

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Abstract

The optimal comfort of occupants in residential buildings within the indoor space is also a function of the physical state of the entire roof. In recent times, the progressive roof decay pattern among residential buildings in Port Harcourt Municipality has raised considerable concerns about the state of indoor spaces, the health of occupants, and the overall impact on space utilisation. This study therefore aimed at assessing how roof decay impacts the indoor space and the end-users in Port Harcourt Municipality. The study adopted a mixed-methods research approach, using a cross-sectional survey research design. The study employed purposive and simple random sampling techniques to select three (3) neighbourhoods (Abuloma, Elekahia and Mgbundungwu) and respondents for the collection of data, with a total of 361 respondents sampled. Structured interviews and questionnaires, along with key informant methods, were used to collect data from respondents, including building occupants, MHDAs, and professionals in the built environment. Checklists, physical observations, and photographs were also used to characterise the roofing condition of residential buildings in the study area. The following are the findings of the study: the poor design, construction pattern of roofs, choice of materials and maintenance culture are the significant factors exacerbating roof decay in the study area; such consequence had resulted to high moisture and dampness, reduction in the usable space, difficulties in operating building components especially doors and windows, and complete reduction in the overall satisfaction of the indoor space by the occupants. It was concluded that professionals in the built environment should consider the tropical climate of the study area as a guide to both the design approach for the roof in this climate and the choice of indoor materials, as well as the size of openings and the amount of light and ventilation required in the study area. The following recommendations are made, roof pattern of residential buildings should be compactable with the peculiar tropical climate, durable indoor materials that is compactable with the climate and regular and timely maintenance should be carried out on both the roof and the indoor spaces, adequate lightening and ventilation should be provided through passively design approach to aid eliminate high moisture content within the indoor spaces.

Keywords: Indoor space, Roof, Roof decay, Optimisation, Port Harcourt municipality

1. INTRODUCTION

A building is more than a mere shelter; it is an artefact, a tangible representation of a society's culture and a visible manifestation of its socio-physical environment. It is purposefully designed to serve specific functions that reflect the social relations and developmental course of a community's workforce. According to Jon (1988), buildings serve as mediums of physical expression and societal identity, acting as symbols that convey cultural and social meaning. Similarly, Abimbola and Adebayo (2015) and the United

Nations Human Settlements Programme (UN-Habitat, 2022) affirm that the built environment encompasses both aesthetic and functional values that reflect societal norms and aspirations. However, these symbolic and functional values can be compromised by the premature deterioration of building components and materials, driven by both external and internal factors. Each building component has a defined and interdependent role, with the roof being particularly critical. As a significant structural element, the roof not only constitutes a substantial portion of construction costs but,

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when properly designed and constructed, can mitigate potential failures in other parts of the building (Obianuju, Chidi, & Ikebueze, 2022).

Amusan (2003) and Adepoju, Adeaga, & Adepoju (2017) also posited that building components and materials, especially the roof, decay at different rates under similar environmental conditions. Therefore, buildings, according to Emechebe and Eze (2021), require specialised skills in planning, design, and construction, as well as good techniques and material selection, because at completion, it is expected that the building can withstand the local climate and also stand the test of time with minimal maintenance.

Port Harcourt City is one of the urban centers with a high agglomeration of industrial activities, located in the South-South geo-political region of Nigeria and the fourth largest city in the country after Lagos, Kano, and Ibadan. Unlike most cities in the country, which are characterised by their economic activities and peculiar climatic conditions, Port Harcourt serves as an international hub for the petroleum industry and government parastatals (Ede, Owei & Akarolo, 2011). This places the city in an advantageous position not only in terms of growth but also in terms of expansion. However, the drastic congestion, climate change, and anthropogenic activities impact building components and materials, presenting a sharp contrast to the expectations of residents and the government's vision of providing a comfortable and healthy environment for citizens (Ede, Owei & Akarolo, 2010).

Onazi, Gaiya, Ola-Adisa, and Zacchaeus (2018) note that government-led or private estates and affordable housing units are frequently created as social measures to resolve housing deficits. In this context, the durability, sustainability, and lifespan of these buildings become critical factors, especially when investigating the root causes of poor indoor quality and unhealthy living conditions. Therefore, this study is essential in assessing the impact of roof decay on the optimisation of indoor residential spaces in Port Harcourt Municipality. It aims to provide architectural insights, particularly in material selection and roof design, that can enhance the quality of indoor environments and improve user comfort and overall liveability.

Aim and Objectives of the Study

The study aimed at assessing the impact of roof decay on the optimisation of residential indoor spaces in selected neighbourhoods of Port Harcourt Municipality.

The objectives of the study are to:

- i. Examine the impacts of roof decay on residential building components and the indoor spaces in the study area; and
- ii. Proffer an architectural measure to mitigate the impact of roof decay on building components and indoor spaces in the study area.

Scope of the Study

This study focused on residential buildings in selected neighbourhoods in Port Harcourt Local Government Area of

Rivers State, Nigeria. The buildings in the selected neighbourhoods comprise single-family bungalows, semi-detached bungalows, and blocks of flats, which residents occupy. It should have been ideal that the study covers all residential buildings in Rivers State, Nigeria but study opted to restrict the scope of the study to three (3) communities which are Abuloma, Elekahia and Mgbundungwu (Mile 1) all in Port Harcourt Municipality, Rivers State which the findings will be used to enhance the conditions of the residential buildings in the country (see figure 1).

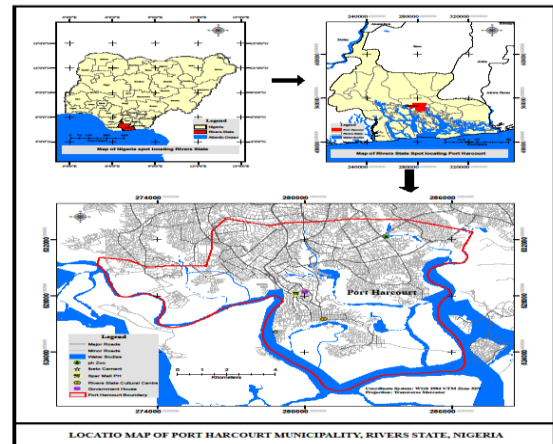


Figure 1: Location Map of Port Harcourt Municipality, Rivers State, Nigeria

Source: Department of Urban and Regional Planning GIS Lab, Rivers State University 2025

2. LITERATURE REVIEW

According to Amusan (2003), Adepoju, Adeaga, and Adepoju (2017), the decay rates of residential building components and materials vary under similar environmental conditions. Therefore, buildings, according to Emechebe and Eze (2021), require specialised skills in planning, design, and construction, as well as good techniques and material selection. This is because, upon completion, it is expected that the building will offer the desired indoor comfort, withstand the local climate, and stand the test of time with minimal maintenance. According to Stephen and Christopher (2010), the external finishes are the determining factor in the aesthetic appearance of the building and the durability of the building fabric. The internal finish helps create a feeling of place and also encourages a healthy indoor environment. The current rate of material decay, which affects the aesthetic quality, durability, and indoor environment, also necessitates the study. Maria-Margarita, (2015) posited in-line with the International Charter for the Conservation and Restoration of Monuments and Sites, (ICOMOS, 1964) that the availability of information on the condition of materials used on the building fabric should help in the identification of the decay cycle, its causes, and the best method of preservation to put-off failure.

Obianuju, Chidi, and Ikebueze (2022), as well as Gupta (2020), further affirm that the early decay of buildings resulting from the impact of roof components significantly affects the indoor space and poses both economic and

environmental burdens not only to the owner but also to municipalities and the nation as a whole. Esau and Pepple (2025) further affirm that the roof is an inseparable component of a residential building, providing holistic protection to the entire structure. Once decay issues set in, the entire building, especially its indoor spaces, undergoes changes that are unhealthy for both humans and pets. Esau and Pepple (2025) further recommended the use of a hip roof, with a pitch of 25⁰ to 45⁰ degrees for easy elimination of warm, humid air and rainwater. However, the resultant effect of roof decay on the indoor space was not accounted for, thereby leaving a gap.

Osuagwu, Okolie, Nkelem, Okoye, and Onwuka (2021) observed that a well-designed, constructed, and maintained roof should sustain and prolong the life of a building. The researchers further observed that during roof construction, the intention to save money for clients and contractors by using substandard and unspecified materials had left a significant dislocation on occupancy, impairing the activities within the building. Osuagwu et al (2021) further asserted that a leaking roof impacts the health of occupants and also induces a high level of decay in building materials and components.

The problems associated with roof structures can either be pathological or catastrophic. Ibe and Oyim (2019) further posited that decay as a problem in the building industry could be studied under three categories: problems initiated from the design stage, problems caused during the construction stage, and difficulties caused during usage resulting from maintenance. However, if issues arising from the design or project execution stage can be well-managed or avoided, the building's service life will be longer and of higher quality (Carretero-Ayuso, Moreno-Cansado & Brito, 2017). Although much has been documented on the causes of building decay, little is known about the impact of roof decay on the indoor space and the health of occupants. In a dilapidation survey of apartment buildings carried out by Saranya and Akansha (2017), it was concluded that there is an excellent concern for professionals in the built environment to concentrate and pay more attention to factors aggravating building decay and impacting the comfort and health of the users Hence, the need for this study.

3. RESEARCH METHODS

The following approach was used to obtain pertinent information and data for the study: a mixed-methods research approach was adopted. Purposive and simple random sampling techniques, along with interviews with key informants, were employed for the collection of field data. A reconnaissance survey was conducted to establish the coordinates and boundaries of each community under study, which were then input into ArcMap and a digital Information System (GIS), as well as OpenStreetMap, to determine the total number of buildings (population) in the selected communities. The study purposively selected three (3) communities, including Abuloma, Elekahia and Mgbundungwu (Mile 1) community, with a total population of six thousand three hundred and sixty-two (6362) buildings.

The study adopted the Krejcie and Morgan (1970) sample size determination table, which was used to determine a sample size of three hundred and sixty-one (361), which were distributed proportionately across the three communities (see Table 1). The head of household was selected using a simple random sampling technique for the study's interviews. However, the key informant interview approach was used to select and interview staff from the Rivers State Ministry of Housing, the Rivers State Housing Authority, and Property Development, as well as other professionals and experts in the built environment, such as Architects and Town Planners, to draw on their professional opinions about the subject under study. Additionally, physical observation and photographs were used to assess the rate of decay of residential building components and materials, as well as the factors responsible and their impact on indoor spaces.

Table 1: Sample Size Distribution Across Studied Neighbourhoods

Sampled Neighbourhoods	Population (Number of Buildings) in the Neighbourhoods	Number of Sampled Buildings
Abuloma	3,632	199
Elekahia	880	54
Mgbundungwu	1,850	108
Total	6,362	361

Source: Researchers' Fieldwork, 2025

4. RESULTS AND DISCUSSION

4.1 Physical Condition of Roof Members

Table 2: Presented a mean score of 4.50 (SD = 0.50) for timber decay, followed closely by roof discolouration with a mean score of 4.46 (SD = 0.58)., Damage or missing components, such as flashing, vents, and shingles, received a mean score of 4.44 (SD = 0.58). Shrinkage and leaking roofing sheets had a mean of 4.28 (SD = 0.61). The growth of biological elements on rooftops has the lowest mean score of 3.94 (SD = 0.90), indicating it may be less prevalent. The grand mean score of 4.32 (SD = 0.63) reinforces the severity and level of decay of roof members across the communities, which affirmed the physical observation in the study area.

Table 2: Physical Condition of Roof Members

Items	Descriptive Statistics				
	N	Minimum	Maximum	Mean	Std. Deviation
Shrinkage and leaking roofing sheets	361	3.00	5.00	4.28	0.61
Roof discolouration (rust or white colouration, holes, missing sections)	361	3.00	5.00	4.46	0.58
Timber decay (mould, mildew, algae and rot)	361	4.00	5.00	4.50	0.50

Damage/missing flashing, vent and shingles	361	3.00	5.00	4.44	0.58
Growth of biological elements on the rooftop	361	2.00	5.00	3.94	0.90
Grand mean				4.32	0.63

Source: Researcher’s Fieldwork, 2025

4.2 Impact of Roof Decay on the Residential Building Components

The study identified the various building components and the level of decay in the indoor space in the study area. The study revealed severe decay in the ceiling finish across the three communities, with Mgbunungwu having the highest mean score of 4.18, followed by Elekahia with a mean score of 4.0, and Abuloma with the lowest mean score of 3.75, indicating a significant impact of roof decay on the ceiling finishes. This reflects the degree of roof decay and the level of neglect by the occupants and building owners in carrying out routine maintenance (see Figure 1). Wall decay follows a similar pattern as the ceiling finish, with Mgbunungwu leading with a mean score of 4.04, Abuloma with 3.68 and Elekahia having 3.5 score, this shows a high level of decay on the walls and its finishes, this was attributed to the continuous exposure of wall components and finishes to high moisture content and temperature fluctuation resulting from decay roof component. The impact on the floor was severe in Elekahia and Mgbunungwu, with a mean score of 3.0 and 3.27, respectively. The low effect on Abuloma was primarily attributed to the durability of its floor finishes. While other components were also affected, the deterioration was to a lesser degree, likely due to their non-exposure to external influences. Notable exceptions included the mechanical and plumbing components in Mgbunungwu and the electrical components in Elekahia, which resulted from negligence and poor maintenance. (see figures 4 and 5). The study recorded that roof decay in residential buildings has a concurrent impact on other building components and a corresponding effect on the indoor space. These findings concur with the observations of Obianuju, Chidi, and Ikebueze (2022), as well as Gupta (2020).

Table 3: Impact of Roof Decay on the Residential Building Components

Building Parts undergoing premature decay	Elekahia N=54		Abuloma N=199		Mgbunungwu (Mile 1) N=108	
	Mean	%	Mean	%	Mean	%
Finishes (Ceilings)	4.00	21.0	3.75	20.0	4.18	21.0

Wall Decay	3.50	19.0	3.68	20.0	4.04	20.0
Window and doors	3.00	16.0	2.94	16.0	3.13	16.0
Floor	3.00	16.0	2.94	16.0	3.27	16.0
Mechanical /plumbing components	2.32	12.0	2.94	16.0	3.57	18.0
Electrical components	3.00	16.0	2.60	14.0	1.97	9.0
Mean Decay	3.14		3.14		4	3.36

Source: Researcher’s Fieldwork, 2024

4.3 Impact of Roof Decay on the Indoor Spaces and the Occupants

The study identified significant adverse effects on the living conditions and overall satisfaction of occupants. The findings indicate that occupants experience a reduction in usable space, with a mean score of 4.48, highlighting the spatial constraints they face due to roof leakages. Dampness on walls, along with broken windows and doors, both of which result from prolonged exposure to moisture, further worsen indoor conditions. These issues encourage mold growth, posing significant health risks, as reflected in a higher mean score of 4.61. Increased maintenance burden, with a mean of 4.48, which suggests that residents are required to invest more time and resources into maintenance. It also revealed that occupants have difficulty operating components, particularly doors and windows, with a mean score of 4.64, indicating significant challenges in daily interactions with their indoor spaces, and a mean score of 4.74 was reported for unhealthy living conditions for both occupants and their pets. The general reduction in the architectural values of the buildings was rated at 4.65, indicating a decline in aesthetic appeal (see Figures 4 and 5). A critical observation was also made by Okogun (2008), Ede (2023), Charles (2022), Ahiaba, Dimuna and Okogun (2008).

Table 4: Impact of Roof Decay on the Indoor spaces and the Occupants

Descriptive Statistics	N	Minim	Maxim	Mean	Std. Deviation
Reduction in usable spaces in the facility on the occupants	361	4.00	5.00	4.48	.5002715
Increase in maintenance burden on the occupants	361	3.00	5.00	4.48	0.50

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Occupants having difficulties operating components especially doors and windows	361	4.00	5.00	4.64	0.56
Damp interior space induces cool and mold growth	361	3.00	5.00	4.61	0.49
Negative image on the occupants and the environment	361	3.00	5.00	4.56	0.64
Increase risk of accidents, injuries and diseases	361	4.00	5.00	4.56	0.59
Unhealthy living conditions for both humans and pets	361	3.00	5.00	4.74	0.44
Presence of pests	361	3.00	5.00	4.74	0.54
Reduced satisfaction due to the occupancy	361	3.00	5.00	4.56	0.60
General reduction in the architectural values of the building	361	3.00	5.00	4.65	0.50
Grand Mean				4.60	0.54

Source: Researchers' Fieldwork, 2025

The severe impact of the decay of building components on indoor spaces triggered a significant response from the occupants, especially in areas with extensive deterioration. The unsatisfactory condition of the indoor spaces due to building decay is as follows: In Mgbunungwu, 55 respondents (50.9%) agreed that the indoor spaces were in a very unsatisfactory state. The study also revealed dissatisfaction among 27 respondents (50%) in Elekahia and 105 users (52.8%) in Abuloma, indicating the prevalent decay and unhealthy indoor conditions in residential buildings within the study area.

Table 5: Occupants' Rating on the Conditions of the Indoor Spaces

Occupants Ratings	Elekahia N=54		Abuloma N=199		Mgbunungwu (Mile 1) N=108	
	N	%	N	%	N	%
Very Satisfactory	0	0	3	1.4	0	0
Satisfactory	0	0	9	4.5	13	12.0
Uncertain	12	22.2	2	11.1	6	5.6

Unsatisfactory	27	50.0	105	52.8	34	31.5
Very unsatisfactory	15	27.8	6	30.2	55	50.9

Source: Researcher's Fieldwork, 2025



Figure 4: Building Condition in the Study



Figure 5: Decay Impact on the Indoor Space Area

Source: Researcher's Fieldwork, 2024

4.4 Experts' Contribution on Building Decay Impact on Indoor Spaces

The expert's rating reveals a concerning trend, with the majority of experts expressing negative assessments. Out of 21 experts, 23.8% rated the impact on indoor spaces as "very unsatisfactory." In contrast, 66.7% rated it as "unsatisfactory," suggesting that nearly 90% of the experts believe the indoor spaces are in a poor state of decay. A smaller portion, 9.53%, rated the situation as "uncertain," indicating some ambiguity in the level of impact. Notably, none of the experts rated the condition of indoor spaces as "satisfactory" or "very

satisfactory," highlighting a clear consensus that there is a greater impact of decay on the indoor spaces (see Table 6).

Table 6: Experts' Rating on the Level of Decay Impact on Indoor Space

S/No	Experts' Rating	No.	%
1	Very satisfactory	-	-
2	Satisfactory	-	-
3	Uncertain	2	9.53
4	Unsatisfactory	14	66.67
5	Very unsatisfactory	5	23.8
Total		21	100

Source: Researchers' Fieldwork, 2024

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The poor condition of residential buildings and their spontaneous component decay have negatively affected indoor spaces. This has led to unhealthy indoor environments and reduced usable space, countering the goals of the World Health Organisation (WHO) and the United Nations-Habitat Global Housing Strategy (UN-Habitat GHS), which promote adequate housing and healthy, hygienic indoor and outdoor environments. The study has identified the contributory impacts of residential building decay on indoor spaces. These include reduction in usable spaces, difficulty using operating components like doors and windows, increase in maintenance burden, damp interior space inducing cooled and mold growth, increase risk of accidents, injuries and diseases and reduction in the architectural values of the building. These attributes have led to poor and unhealthy indoor spaces in residential buildings in the study area, which both residents and professionals have observed to be unsatisfactory. This study has also contributed to the body of knowledge in building science and services in architecture, as well as in determining the best approach to maintain a good and high-quality indoor space in the study area.

5.2 Recommendations

The recommendations suggested to ameliorate the impact of building decay on the indoor space include the following:

- i. The choice of materials should be made from the design stage and should be the responsibility of the architect or material expert.
- ii. A thorough building survey or diagnosis should be conducted to identify the problem and its source before remedial actions are initiated.
 - i. Regular and timely maintenance should be carried out at least once every two years to keep residential building components and finishes in a functional and healthy conditions.
 - ii. Maintenance excesses should be addressed on both exterior and interior fabric. They should be the

responsibility of both occupants and the building owner, for both private and government-owned residential buildings.

- iii. Materials for external envelop should have the ability to resist capillary action and ingress of moisture into the indoor space to eliminate mold growth and dampness in the interior spaces.

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