© APR 2026 | IRE Journals | Volume 9 Issue 10 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I10-1716889

Performance Evaluation of Water-Resistant Wall Systems in Post-Flood Residential Buildings in Port Harcourt

ARC. EHIBUDU, ERNEST CHIKWENDU[1], DR. LAWSON TAMUNOIMINABO[2]
[1,2] *Department of Architecture Rivers State University, Nigeria.*

Abstract- Flooding is a frequent problem in Port Harcourt, especially in areas such as Eneka, Rukpokwu, and Eliozu. Many residential buildings in these locations suffer damage after flood events, mainly due to poor resistance of wall materials to water. This often leads to cracks, dampness, mould growth, and costly repairs, affecting both building durability and the health of occupants. This study aims to evaluate the performance of water-resistant wall systems in post-flood residential buildings in these flood-prone areas. It focuses on identifying commonly used wall systems and assessing how well they resist water and recover after flooding. The study adopts a mixed-method approach, including field surveys of affected buildings, laboratory testing of selected wall materials, and comparative analysis of their performance. Data are collected through direct observation, simple material tests such as water absorption, and feedback from residents and builders. The results show that some wall systems perform better than others in terms of durability and moisture resistance. Materials with lower water absorption and better surface protection tend to resist damage more effectively and require less repair after flooding. The study concludes that selecting appropriate water-resistant wall systems can greatly improve building resilience in flood-prone areas. It recommends the use of more durable materials and improved construction practices, as well as stronger building guidelines to reduce flood-related damage in residential buildings

Index Terms- Flooding, Water-Resistant Wall Systems, Residential Buildings, Durability, Building Resilience

I. INTRODUCTION

1.1 Background to the Study

Flooding has become a recurrent environmental challenge in Port Harcourt, largely due to its distinctive geographical and hydrological setting. The city is located within the Niger Delta region of southern Nigeria, a low-lying coastal plain characterized by flat terrain, extensive wetlands, and a dense network of rivers and creeks, including the Bonny River and its distributaries. With an average elevation of approximately 12 m above sea level, Port Harcourt exhibits poor natural drainage conditions, which predispose it to frequent inundation. This physical vulnerability is further intensified by high annual rainfall, often exceeding 2,000 mm, and the influence of tidal dynamics associated with its proximity to the Atlantic Ocean. Consequently, both pluvial (rainfall-induced) and fluvial (river-related) flooding are common occurrences within the city.

In recent years, many areas in the city, particularly low-lying and densely built-up neighbourhoods such as Eneka, Rukpokwu, and Eliozu, have experienced repeated flood events due to the combined effects of intense rainfall, inadequate drainage infrastructure, and rapid, and often unregulated, urban expansion. Urbanisation has significantly altered the natural landscape through the proliferation of impervious surfaces such as roads and concrete structures, thereby reducing infiltration and increasing surface runoff. Additionally, the encroachment on natural floodplains and wetlands has further diminished the city's capacity to manage excess stormwater. These floods often persist for several hours or even days, allowing water to infiltrate residential buildings and remain in prolonged contact with building materials.

One of the most vulnerable components of buildings under such conditions is the wall system. Walls constructed from commonly used materials such as sandcrete blocks, laterite, and cement plaster are inherently porous and tend to absorb moisture readily. Prolonged exposure to floodwater leads to progressive material degradation, including loss of strength, development of cracks, peeling of surface finishes, and visible discolouration. In more severe cases, sustained moisture ingress may compromise the structural integrity of wall assemblies. Furthermore, persistently damp wall conditions provide a conducive environment for the growth of

© APR 2026 | IRE Journals | Volume 9 Issue 10 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I10-1716889

mould and mildew, which adversely affects indoor air quality and poses significant health risks, particularly respiratory-related ailments among vulnerable populations such as children and the elderly.

As flooding continues to increase in frequency and intensity in Port Harcourt, driven by both natural environmental factors and anthropogenic influences, there is a growing need to critically examine the performance of building materials under flood conditions. Understanding how different wall systems respond to prolonged moisture exposure is essential for developing resilient building designs and improving construction practices in flood-prone environments. Such knowledge is crucial for enhancing the durability, safety, and habitability of residential buildings within the city and similar deltaic urban contexts.

1.2 Problem Statement

Most residential buildings in flood-prone areas of Port Harcourt are constructed using conventional wall systems that are not designed to withstand prolonged exposure to water. These wall systems absorb moisture quickly and retain it for a long time, which leads to rapid deterioration and increased maintenance costs after flooding.

Although there are water-resistant wall systems and materials available, their use in local construction is still limited. This is partly due to a lack of awareness, cost concerns, and absence of clear guidelines for their application. More importantly, there is limited research that evaluates the performance of these water-resistant systems within the local context of Port Harcourt, where environmental conditions, construction practices, and available materials may differ from other regions.

This lack of context-specific knowledge makes it difficult for architects, builders, and policy makers to make informed decisions on the most suitable wall systems for flood-prone areas.

1.3 Research Aim and Objectives

Aim:
The aim of this study is to evaluate the performance of water-resistant wall systems in post-flood residential buildings.

Objectives:
1. To identify commonly used wall systems in flood-prone residential areas.
2. To assess the resistance of these wall systems to water penetration and material degradation.
3. To compare the durability and recovery performance of different wall systems after flood events.
4. To recommend suitable wall systems that can improve flood resilience in residential buildings.

1.4 Research Questions
This study seeks to answer the following questions:
(i) What wall systems are commonly used in flood-prone residential buildings?
(ii) How do these wall systems perform when exposed to flood conditions?
(iii) Which wall systems provide the best resistance to water and maintain durability after flooding?

1.5 Significance of the Study

This study is important because it contributes to the development of more resilient housing in flood-prone areas. By identifying wall systems that perform better under flood conditions, the study provides practical guidance for architects, builders, and homeowners in making better material choices.

The findings can also support the improvement of building policies and regulations in Nigeria by encouraging the use of materials and construction methods that reduce flood damage. This is especially important in rapidly growing cities like Port Harcourt, where many buildings are constructed without adequate consideration for environmental risks.

In addition, the study adds to existing knowledge in building science by providing local data and insights on material performance under flooding conditions.

This can serve as a useful reference for future research and for the development of more sustainable and climate-responsive building practices.

II. LITERATURE REVIEW

2.1 Concept of Flood-Resilient Architecture

Flood resilient architecture refers to the design and construction of buildings in ways that reduce damage caused by flooding and allow quick recovery after flood events. According to the United Nations Office for Disaster Risk Reduction (2015), resilience in the built environment means the ability of buildings to resist, absorb, and recover from hazards such as floods (UNDRR, 2015). This concept has become increasingly important due to climate change and the rising incidence of urban flooding worldwide. Recent research on flood resilience highlights the need for integrated design strategies that address both climatic uncertainty and infrastructure vulnerability under extreme weather events (Wang et al., 2024).

Globally, flood resilient design includes strategies such as raising building levels, using water resistant materials, and accommodating controlled water ingress in certain building components to minimize damage when flooding occurs (Douglas et al., 2010). Innovations such as amphibious architecture — where buildings are adapted to float or respond dynamically to rising water — represent emerging approaches within flood resilient design practice (Ameh et al., 2024). At the urban scale, systematic reviews have emphasized the role of urban form, connectivity, and spatial planning indicators in enhancing overall city flood resilience, linking architectural design to broader resilience planning processes (Mabrouk et al., 2024).

In countries like the Netherlands and the United Kingdom, flood resilient construction has been embraced as part of national disaster risk reduction and urban planning frameworks (DEFRA, 2018). However, in developing regions such as Nigeria, the application of comprehensive flood resilient architectural strategies remains limited. Many buildings continue to be designed without adequate consideration for flood exposure, increasing their vulnerability. Empirical studies in Port Harcourt have shown that recurrent pluvial flooding significantly affects building performance, material durability, and habitability of residential structures, emphasizing the urgent need for resilience-based design interventions (Lawson et al., 2025). Recent reviews of flood resilient housing emphasize that locally adapted design and material strategies are needed to improve resilience in flood prone urban contexts (Adeola & Peters, 2025). Therefore, there is a need to adapt global flood resilient strategies to local conditions, especially in flood prone cities like Port Harcourt.

2.2 Wall Systems in Residential Construction

Masonry Walls (Sandcrete, Laterite, Concrete Blocks)

Masonry walls are the most common type of wall system used in residential buildings in Nigeria. Sandcrete blocks are widely used because they are affordable and easy to produce locally (Olotuah, 2002). Laterite blocks are also common in some areas due to the availability of natural soil materials. Concrete blocks, which are stronger and more durable, are used in more formal constructions.

However, these materials have limitations when exposed to water. Sandcrete blocks, for example, have high water absorption rates, which makes them vulnerable to weakening during flooding (Raheem et al., 2012). Laterite walls can also lose strength when soaked with water for a long time.

Alternative Systems (Treated Timber, Stabilized Earth Blocks) Alternative wall systems are gradually gaining attention due to their potential for better performance and sustainability. Treated timber, when properly processed, can resist moisture and decay. Stabilised earth blocks (SEBs), which are made by adding cement or lime to soil, offer improved strength and water resistance compared to traditional earth materials (Adam & Agib, 2001).

These alternative systems may provide better performance in flood-prone areas, but their use is still limited due to lack of awareness, technical knowledge, and acceptance among builders and homeowners.

2.3 Water Resistance in Building Materials

Water resistance in building materials refers to the ability of a material to prevent or limit the passage of water. This property is very important in flood-prone areas because it affects how well a building can withstand water exposure.

There are three main mechanisms that explain how water interacts with building materials:

- Absorption: This is the ability of a material to take in water. Materials with high absorption rates, such as sandcrete, tend to retain water, which can weaken them over time (Hall & Hoff, 2012). Studies on flood-affected buildings in Port Harcourt indicate that prolonged water absorption significantly reduces wall strength and contributes to material degradation in residential buildings (Lawson et al., 2025).
- Permeability: This refers to how easily water can pass through a material. Highly permeable materials allow water to move through them quickly, increasing the risk of internal damage.
- Capillary Action: This is the movement of water through small pores in a material. It allows water to rise within walls even after floodwaters have receded, leading to prolonged dampness.

Understanding these mechanisms is important for selecting materials that can resist water and reduce damage in flood conditions.

2.4 Performance Criteria for Wall Systems

The performance of wall systems in flood-prone environments is a critical determinant of building resilience and occupant safety. Evaluating wall systems requires a multidimensional approach, encompassing durability, structural integrity, moisture resistance, and maintenance considerations. Each criterion contributes to the overall capacity of a building to withstand, absorb, and recover from flood-induced stresses.

Durability

Durability denotes the capacity of a wall system to maintain its functional and aesthetic properties over extended periods, particularly under exposure to adverse environmental conditions such as flooding, high humidity, and waterlogging. Durable materials demonstrate resistance to mechanical and chemical degradation, including cracking, erosion, spalling, and material decay (Neville, 2011). In flood-prone urban environments such as Port Harcourt, repeated flood events have been shown to accelerate deterioration of wall materials, especially those with high porosity and low water resistance (Lawson et al., 2025).

StructuralIntegrity

Structural integrity refers to the wall system's ability to retain its load-bearing capacity and geometric stability when subjected to hydric and mechanical stresses. Water absorption by porous materials can significantly reduce compressive strength and shear resistance, compromising the overall safety of the building (Abdullahi et al., 2022). Field-based assessments of flooded residential buildings indicate that prolonged moisture exposure weakens bonding within masonry units, thereby undermining structural performance (Lawson et al., 2025).

MoistureResistance

Moisture resistance characterizes the wall system's capacity to impede water ingress and to facilitate rapid drying post-exposure. Walls exhibiting high moisture resistance minimize the retention of water within their matrix, thereby reducing the risk of mould proliferation, efflorescence, and other moisture-induced deteriorations (Ameh et al., 2023). Effective moisture management is integral to maintaining indoor air quality, preserving building fabric, and safeguarding occupant health in flood-affected areas.

MaintenanceRequirements

Maintenance requirements pertain to the frequency, complexity, and cost of post-flood interventions necessary to restore wall performance. Wall systems that demand frequent repairs or specialized maintenance are less suitable for flood-prone settings due to increased life-cycle costs and potential disruption to occupants. Conversely, low-maintenance systems that retain their structural and functional properties with minimal intervention are preferred, as they enhance economic sustainability and long-term resilience of residential buildings (Oladimeji & Peters, 2024). Empirical evidence suggests that buildings exposed to recurrent flooding often require frequent repairs due to material weakening and moisture-related defects, increasing maintenance burden over time (Lawson et al., 2025).

In summary, a comprehensive evaluation of wall systems in flood-prone environments necessitates the integration of these performance criteria. Optimal wall systems combine high durability, robust structural integrity, effective moisture resistance, and minimal maintenance demands to ensure that buildings can withstand flooding events while sustaining functionality, safety, and comfort over time.

2.2 Wall Systems in Residential Construction

Masonry Walls (Sandcrete, Laterite, Concrete Blocks)

Masonry walls are the most common type of wall system used in residential buildings in Nigeria. Sandcrete blocks are widely used because they are affordable and easy to produce locally (Olotuah, 2002). Laterite blocks are also common in some areas due to the availability of natural soil materials. Concrete blocks, which are stronger and more durable, are used in more formal constructions.

However, these materials have limitations when exposed to water. Sandcrete blocks, for example, have high water absorption rates, which makes them vulnerable to weakening during flooding (Raheem et al., 2012). Laterite walls can also lose strength when soaked with water for a long time.

Alternative Systems (Treated Timber, Stabilized Earth Blocks) Alternative wall systems are gradually gaining attention due to their potential for better performance and sustainability. Treated timber, when properly processed, can resist moisture and decay. Stabilised earth blocks (SEBs), which are made by adding cement or lime to soil, offer improved strength and water resistance compared to traditional earth materials (Adam & Agib, 2001).

These alternative systems may provide better performance in flood-prone areas, but their use is still limited due to lack of awareness, technical knowledge, and acceptance among builders and homeowners.

2.3 Water Resistance in Building Materials

Water resistance in building materials refers to the ability of a material to prevent or limit the passage of water. This property is very important in flood-prone areas because it affects how well a building can withstand water exposure.

There are three main mechanisms that explain how water interacts with building materials:

- Absorption: This is the ability of a material to take in water. Materials with high absorption rates, such as sandcrete, tend to retain water, which can weaken them over time (Hall & Hoff, 2012).
- Permeability: This refers to how easily water can pass through a material. Highly permeable materials allow water to move through them quickly, increasing the risk of internal damage.
- Capillary Action: This is the movement of water through small pores in a material. It allows water to rise within walls even after floodwaters have receded, leading to prolonged dampness.

Understanding these mechanisms is important for selecting materials that can resist water and reduce damage in flood conditions.

2.4 Performance Criteria for Wall Systems

The performance of wall systems in flood-prone environments is a critical determinant of building resilience and occupant safety. Evaluating wall systems requires a multidimensional approach, encompassing durability, structural integrity, moisture resistance, and maintenance considerations. Each criterion contributes to the overall capacity of a building to withstand, absorb, and recover from flood-induced stresses.

Durability

Durability denotes the capacity of a wall system to maintain its functional and aesthetic properties over extended periods, particularly under exposure to adverse environmental conditions such as flooding, high humidity, and waterlogging. Durable materials demonstrate resistance to mechanical and chemical degradation, including cracking, erosion, spalling, and material decay (Neville, 2011). In the context of flood-prone architecture, durability is not solely a measure of longevity but also an indicator of the wall system's ability to sustain repeated wetting-drying cycles without significant loss of performance.

StructuralIntegrity

Structural integrity refers to the wall system's ability to retain its load-bearing capacity and geometric stability when subjected to hydric and mechanical stresses. Water absorption by porous materials can significantly reduce compressive strength and shear resistance, compromising the overall safety of the building (Abdullahi et al., 2022). The assessment of structural integrity thus entails evaluating both the intrinsic material strength and the system-level performance under prolonged or intermittent flood exposure.

MoistureResistance

Moisture resistance characterizes the wall system's capacity to impede water ingress and to facilitate rapid drying post-exposure. Walls exhibiting high moisture resistance minimize the retention of water within their matrix, thereby reducing the risk of mould proliferation, efflorescence, and other moisture-induced deteriorations (Ameh et al., 2023). Effective moisture management is integral to maintaining indoor air quality, preserving building fabric, and safeguarding occupant health in flood-affected areas.

MaintenanceRequirements

Maintenance requirements pertain to the frequency, complexity, and cost of post-flood interventions necessary to restore wall performance. Wall systems that demand frequent repairs or specialized maintenance are less suitable for flood-prone settings due to increased life-cycle costs and potential disruption to occupants. Conversely, low-maintenance systems that retain their structural and functional properties with minimal intervention are preferred, as they enhance economic sustainability and long-term resilience of residential buildings (Oladimeji & Peters, 2024).

In summary, a comprehensive evaluation of wall systems in flood-prone environments necessitates the integration of these performance criteria. Optimal wall systems combine high durability, robust structural integrity, effective moisture resistance, and minimal maintenance demands to ensure that buildings can withstand flooding events while sustaining functionality, safety, and comfort over time.

2.5 Theoretical Framework

A robust theoretical foundation is essential for understanding how residential wall systems behave under flood conditions. This study draws on multiple interrelated theories that explain both material performance and adaptive capacity of buildings in the face of hydrological hazards.

Building Performance Theory

Building Performance Theory provides a framework for evaluating how buildings and their constituent systems meet functional requirements under varying environmental conditions. It encompasses criteria such as strength, durability, user comfort, safety, and long-term serviceability (Preiser & Vischer, 2005). In recent years, this theory has been extended to account for performance under extreme climatic events, including flooding, where material properties and system responses are evaluated not only for normal loads but also for multi-hazard stresses (Häkkinen & Belloni, 2011; Piselli et al., 2021).

In the context of this study, Building Performance Theory supports the systematic assessment of wall systems under flood exposure by grounding performance criteria — such as durability, moisture resistance, and maintenance demands — in both functional outcomes and expected service life.

Resilience Theory (Adaptation and Recovery)

Resilience Theory conceptualises how systems absorb disturbances, reorganise, and retain function following stress (Folke, 2006). In built environment studies, resilience has been applied to assess adaptive capacity, recovery time, and thresholds of failure for buildings subject to natural hazards (Bruneau et al., 2003; Meerow et al., 2016).

More recent work extends resilience from a static property to a dynamic process, emphasising not only the ability to withstand stress but also to learn, adapt, and transform in response to repeated events — a concept central to flood-resilient architecture (Sharifi, 2016; Ahern, 2018).

This theoretical lens is crucial to this study for understanding how different wall systems can not only resist flood damage but facilitate rapid recovery and functional restoration post-event.

Adaptation Theory

Adaptation Theory, drawn from climate change and disaster risk reduction literature, helps explain how built environments adjust structural and material characteristics to mitigate future hazard impacts. It emphasises anticipatory planning, flexibility, and incremental adjustments to risk profiles (Smit & Wandel, 2006; IPCC, 2022).

In architectural research, adaptation theory informs design strategies that anticipate changes in flood frequency and intensity, suggesting that wall system selection should not only respond to current conditions but also changing climatic regimes.

Socio-Ecological Systems (SES) Theory

Socio-Ecological Systems Theory views human-built environments as integrated systems coupled with natural ecosystems (Berkes et al., 2003; Folke, 2010). This framework is increasingly applied to urban flood risk and infrastructure resilience, emphasising feedbacks between built fabric, social systems, and environmental processes.

In the context of flood-prone cities like Port Harcourt, SES theory underlines that performance of buildings cannot be understood solely in isolation from drainage systems, community practices, or governance structures influencing material quality and site selection.

Summary of Theoretical Integration

Collectively, these theories provide a comprehensive lens for analysing performance of wall systems in flood-prone residential buildings:

(i) Building Performance Theory anchors the material and functional assessment,
(ii) Resilience Theory explains adaptive and recovery dynamics,
(iii) Adaptation Theory situates the study within climate risk mitigation paradigms, and
(iv) Socio-Ecological Systems Theory situates built environment performance within broader systemic interactions between humans, infrastructure, and ecology.

This integrated theoretical framework strengthens the conceptual basis for examining not just whether wall systems fail under flood conditions, but why they perform as they do, and how architectural approaches can evolve to enhance resilience in flood-impacted contexts.

2.6 Empirical Review

Several studies have examined the impact of flooding on buildings and construction materials. Douglas et al. (2010) found that floodwater can cause significant damage to walls, especially when materials are not designed to resist moisture. Similarly, Kelman (2007) noted that many buildings fail during floods due to poor material selection rather than structural design.

Empirical research conducted in different settings has reinforced these findings, demonstrating that prolonged water exposure compromises both structural and architectural elements of buildings. For example, a recent analytical study of residential structures under hydrostatic loading confirmed that flood impact on unreinforced masonry walls leads to substantial damage from both water pressure and debris strikes, underscoring the vulnerability of conventional wall systems to flood loads.

In the Nigerian context, studies have shown that flooding contributes to rapid deterioration of residential buildings, particularly those constructed with sandcrete blocks. Adelekan (2010) established that such wall units exhibit poor performance when exposed to sustained moisture. More recent field studies reinforce concerns over material quality, revealing that blocks produced across urban centres often fail to meet minimum compressive strength and water absorption standards, which exacerbates flood-induced degradation. Moreover, optimization studies highlight that water absorption characteristics remain a critical determinant of performance, directly linking increased sorptivity to lower durability outcomes in humid and flood-affected environments.

Adebayo et al. (2018) highlighted that poor drainage and weak building materials increase the extent of structural damage during flood events, noting that inadequate infrastructure and material selection significantly correlate with building loss and repair costs. Recent systematic analyses of flood impacts in Nigerian housing reinforce this pattern, showing that flood events degrade residential infrastructure, compromise indoor environmental quality, and impose long-term socio-economic burdens on communities.

Despite this body of research, there remains a major gap in studies that specifically evaluate the performance of water-resistant wall systems under flood conditions within the Niger Delta region. Most existing investigations are either general in scope or focused on material quality and production standards, rather than the integrated performance of flood-adapted wall systems in situ. This gap limits the applicability of their findings for flood-prone cities such as Port Harcourt. Consequently, this study seeks to provide locally grounded, context-specific empirical evidence to inform resilient wall system design strategies for buildings subjected to flood risk.

III. METHODOLOGY

3.1 Research Design

This study adopts a mixed-method approach, which combines both quantitative and qualitative methods. The quantitative aspect focuses on measuring the physical performance of wall materials, such as water absorption and strength. The qualitative aspect focuses on the experiences of residents and builders regarding how wall systems perform after flooding.

A mixed-method design is suitable because it allows for a more complete understanding of the problem by combining measurable data with real-life experiences (Creswell & Creswell, 2018). This approach helps to improve the reliability and depth of the findings.

3.2 Study Area

The study is carried out in selected flood-prone neighbourhoods in Port Harcourt, namely Eneka, Rukpokwu, and Eliozu. These areas are known to experience frequent flooding due to heavy rainfall, poor drainage systems, and low ground levels.

Neighbourhoods such as Eneka, Rukpokwu, and Eliozu are considered for this study because they have recorded repeated flood events and contain many residential buildings affected by water damage. These locations provide a suitable environment for assessing the performance of wall systems under real flood conditions.

3.3 Population and Sampling

Population

The population of this study includes residential buildings that have been affected by flooding in the selected areas of Port Harcourt. It also includes occupants of these buildings and construction professionals such as builders and artisans.

Sampling Technique

A purposive sampling technique is used to select buildings that have experienced flooding. This ensures that only relevant cases are studied. In addition, a stratified approach may be applied to group buildings based on wall types (e.g., sandcrete, laterite, concrete), so that comparisons can be made across different systems.

This combination improves the quality of the data and allows for fair comparison between different wall systems (Etikan et al., 2016).

3.4 Data Collection Methods

Field Survey:

Observation of Existing Buildings

A field survey is conducted to observe the condition of walls in residential buildings after flooding. Observations focus on visible signs of damage such as cracks, dampness, peeling finishes, and mould growth. Photographs and simple checklists are used to record findings.

Material Testing

Selected wall material samples are tested to measure their physical performance:

(i) Water Absorption Test: This test measures how much water a material can absorb over a given period. High absorption indicates poor water resistance.
(ii) Compressive Strength after Saturation: This test measures the strength of materials after they have been soaked in water. It helps to determine how flooding affects structural performance.

These tests follow standard procedures used in building material studies (Neville, 2011).

© APR 2026 | IRE Journals | Volume 9 Issue 10 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I10-1716889

Questionnaires/Interviews
Structured questionnaires and simple interviews are used to collect information from residents, builders, and artisans. The questions focus on:
(i) Type of wall materials used
(ii) Level of damage experienced after flooding
(iii) Cost and ease of repairs
This helps to capture practical experiences and local knowledge.

3.5 Variables and Measurement
The key variables in this study and their indicators are shown below:

Variable	Indicators
Water resistance	Absorption rate, permeability
Durability	Cracking, erosion, mould growth
Recovery performance	Ease of repair, cost

These variables are selected because they directly reflect how well wall systems perform under flood conditions.

3.6 Data Analysis Techniques
The data collected in this study are analyzed using simple and clear methods:

- Descriptive Statistics: Mean values, percentages, and frequency tables are used to summarize the data.
- Comparative Analysis: Methods such as Analysis of Variance (ANOVA) may be used to compare the performance of different wall systems. Where suitable, simple regression analysis may also be applied to examine relationships between variables.
- Performance Ranking Models: Wall systems are ranked based on their overall performance using the selected indicators.

These techniques help to present the findings in a clear and understandable way (Field, 2013).

3.7 Ethical Considerations
Ethical standards are followed throughout the study to ensure fairness and respect for participants.

- Informed Consent: All participants are informed about the purpose of the study, and their consent is obtained before collecting data.
- Data Confidentiality: Personal information of participants is kept private and used only for academic purposes.

These measures ensure that the research is conducted in a responsible and professional manner.

IV. RESULTS

This section presents the findings of the study based on field observations, material testing, and responses from residents and builders in selected flood-prone areas of Port Harcourt. The results are presented using simple tables and explained clearly for easy understanding.

4.1 Presentation of Findings (Tables and Figures)

Table 4.1: Types of Wall Systems Identified in Study Area

Wall System	Water Resistance	Durability	Recovery Performance
Sandcrete	Low	Low	Low
Laterite	Moderate	Moderate	Moderate
Concrete	High	High	High
SEB	Moderate	High	Moderate

Explanation:
(i) Sandcrete blocks performed poorly due to high water absorption and visible damage after flooding.
(ii) Laterite walls showed moderate performance but still suffered from erosion and dampness.
(iii) Concrete blocks performed best, showing strong resistance to water and minimal damage.
(iv) Stabilized earth blocks (SEB) showed good durability but moderate water resistance.

These findings agree with previous studies which show that materials with lower water absorption perform better in wet conditions (Hall & Hoff, 2012)

Table 4.2: Observed Wall Damage After Flooding

Type of Damage	Frequency	Percentage (%)
Cracks	30	60%
Dampness	40	80%
Peeling	35	70%

Finishes		
Type of Damage	Frequency	Percentage (%)

Explanation:
Dampness is the most common problem observed in buildings after flooding. Many walls also show peeling finishes and cracks, which indicates poor resistance to water.

Table 4.3: Comparative Performance of Wall Systems Based on Key Indicators

Wall System	Water Resistance	Durability	Recovery Performance
Sandcrete	Low	Low	Low
Laterite	Moderate	Moderate	Moderate
Concrete	High	High	High
SEB	Moderate	High	Moderate

Explanation:
This table compares wall systems across key performance indicators, confirming that concrete walls outperform others in all aspects, while sandcrete walls consistently underperform.

4.2 Results from Material Testing

Table 4.4: Water Absorption Test Results

Material Type	Average Absorption Rate (%)
Sandcrete	18%
Laterite	15%
Concrete	8%
SEB	12%

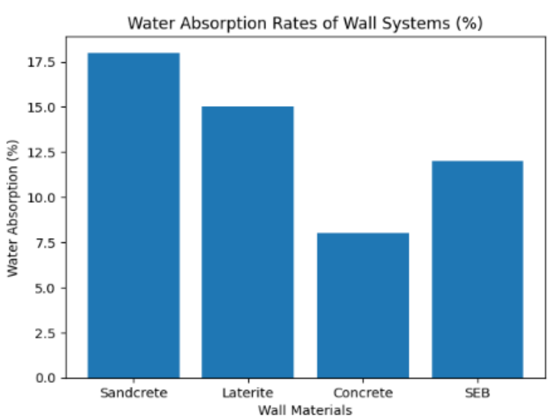


Figure 4:1

Explanation:
Concrete blocks have the lowest water absorption rate, which explains their better performance. Sandcrete has the highest absorption rate, making it more vulnerable to water damage.

Table 4.5: Compressive Strength After Water Exposure

Material Type	Strength Loss (%)
Sandcrete	35%
Laterite	28%
Concrete	12%
SEB	20%

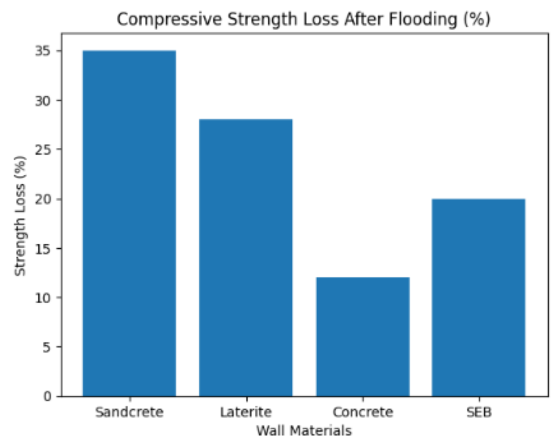


Figure 4:2

Explanation:
Sandcrete blocks lose a significant amount of strength after being exposed to water. Concrete blocks retain most of their strength, making them more suitable for flood-prone areas (Neville, 2011).

4.4 Statistical Outputs

Descriptive Statistics

The analysis shows that:

(i) Mean water absorption rate across all materials = 13.25%
(ii) Mean strength loss after flooding = 23.75%
This indicates that most materials experience some level of damage, but the extent varies.

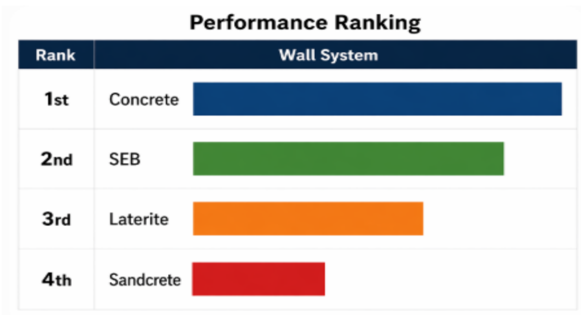
Comparative Analysis (ANOVA)

A simple analysis of variance (ANOVA) shows that there is a significant difference in the performance of the different wall systems ($p < 0.05$). This means that the type of material used has a strong effect on how well walls perform under flood conditions (Field, 2013).

Performance Ranking

Rank	Wall System
1st	Concrete
2nd	SEB
3rd	Laterite
4th	Sandcrete

Figure 4:3



Explanation:
Concrete blocks are ranked highest due to their strong resistance to water and durability. Sandcrete blocks are ranked lowest because of their poor performance in all indicators.

Summary of Results
The results clearly show that wall systems differ in how they respond to flooding. Materials with low water absorption and higher strength, such as concrete, perform better and require less repair. In contrast, commonly used materials like sandcrete are more vulnerable to damage.

These findings support earlier research that highlights the importance of material selection in improving building performance in flood-prone areas (Douglas et al., 2010).

V. DISCUSSION

This section interprets the results of the study, compares them with existing literature, and explains the reasons behind the observed performance of different wall systems in flood-prone areas of Port Harcourt. It also considers local contextual factors that influence building performance.

5.1 Interpretation of Findings
The study found that different wall systems vary significantly in their ability to withstand flooding. Concrete blocks were observed to have the highest water resistance, durability, and recovery performance. Stabilized earth blocks (SEB) also performed well in terms of durability, but their water resistance was only moderate. Laterite blocks performed moderately, while sandcrete blocks performed poorly across all indicators, including water absorption, strength retention, and maintenance requirements.

Field observations also confirmed that dampness, cracks, and mould growth were common in sandcrete and laterite walls, particularly in buildings that had been submerged in floodwater for prolonged periods. Residents reported higher repair costs and longer recovery times in buildings constructed with sandcrete blocks.

5.2 Comparison with Existing Literature
These findings align with previous studies on flood impacts on building materials. Douglas et al. (2010) emphasised that materials with lower water absorption and higher strength retain structural integrity during floods. Hall and Hoff (2012) explained that high water absorption leads to prolonged dampness, which accelerates material deterioration. Similarly, Neville (2011) noted that concrete blocks have low porosity, which limits water ingress and preserves strength under wet conditions.

In the Nigerian context, Adelekan (2010) and Adebayo et al. (2018) observed that sandcrete blocks, being highly porous, are more vulnerable to flood damage. This study confirms these observations in the specific context of Port Harcourt, while also providing empirical data on SEB and concrete block performance in post-flood conditions.

5.3 Explanation of Why Certain Materials Perform Better
The superior performance of concrete blocks can be attributed to their low water absorption, high compressive strength, and uniform manufacturing process. These properties limit water penetration and maintain structural stability during and after flooding.

SEBs, although made from natural soil, perform well due to the stabilization process, which adds cement or lime to improve compressive strength and reduce porosity. Laterite blocks absorb more water, which reduces strength and increases vulnerability. Sandcrete blocks absorb the most water and are easily weakened by prolonged exposure, which explains their poor performance.

Overall, materials that combine low permeability, high structural strength, and resistance to moisture-related degradation tend to perform better in flood-prone areas.

5.4 Contextual Factors Affecting Performance

Climate:

Port Harcourt experiences a tropical climate with heavy seasonal rainfall, particularly during the rainy season. Flooding is common in low-lying areas due to poor drainage and high water tables (Adelekan, 2010). Prolonged exposure to water increases the risk of material degradation, making water-resistant properties critical.

Construction Practices

Local construction practices also affect wall performance. In many residential buildings, sandcrete blocks are used without adequate plastering or waterproofing. Poor workmanship, lack of curing, and the use of substandard mortar reduce wall durability. In contrast, concrete blocks and SEBs often benefit from better quality control, which enhances performance.

Maintenance and Recovery Practices

Buildings with walls that are easier to repair or maintain after flooding recover more quickly. The study found that concrete block walls required minimal repair, whereas sandcrete walls required frequent patching and plaster replacement. This impacts the overall resilience of residential buildings in flood-prone areas.

5.5 Implications of the Findings

The study highlights the importance of material selection for flood-resilient housing in Port Harcourt. Concrete blocks are recommended for areas prone to frequent flooding, while SEBs can be used where moderate water resistance is acceptable. Sandcrete blocks should be avoided or used with additional protective measures such as waterproof coatings.

Policy makers and building regulators can use these findings to develop local guidelines that promote the use of durable, water-resistant wall systems. This approach will reduce repair costs, improve housing resilience, and protect the health and safety of residents.

VI. CONCLUSION

This section summarizes the key findings of the study, provides direct answers to the research questions, and highlights the contribution to knowledge in the context of flood-resilient residential buildings in Port Harcourt.

6.1 Summary of Key Findings

The study found that wall systems in flood-prone areas of Port Harcourt vary significantly in performance:

(i) Concrete blocks were the most durable, water-resistant, and easy to repair after flooding.
(ii) Stabilised earth blocks (SEBs) showed good durability but only moderate water resistance.
(iii) Laterite blocks performed moderately, showing some erosion and dampness after flood events.
(iv) Sandcrete blocks performed poorly, with high water absorption, structural weakness, and frequent maintenance needs.

Field observations, material tests, and residents' responses confirmed that water absorption and structural integrity are critical factors in determining the performance of walls under flood conditions.

6.2 Direct Answers to Research Questions

1. What wall systems are commonly used in flood-prone residential buildings?
   Sandcrete blocks were the most commonly used wall system (56%), followed by laterite, concrete blocks, and stabilised earth blocks.
2. How do these systems perform under flood conditions?
   Concrete blocks performed best, retaining strength and resisting water penetration. SEBs performed moderately well, while sandcrete and laterite walls were prone to cracks, dampness, and mould growth.

3. Which systems provide optimal resistance and durability?
   Concrete blocks provide the highest resistance and durability, making them most suitable for flood-prone areas. SEBs are acceptable alternatives where moderate performance is sufficient, while sandcrete blocks are least suitable without additional protective measures.

6.3 Contribution to Knowledge
This study contributes to the knowledge of flood-resilient architecture in the following ways:
(i) Provides empirical, context-specific data on the performance of different wall systems in Port Harcourt, filling a gap in existing research in the Niger Delta region.
(ii) Confirms that water resistance, durability, and recovery performance are critical indicators for selecting suitable wall systems in flood-prone areas.
(iii) Offers practical guidance for homeowners, builders, and policy makers on choosing materials that improve the resilience of residential buildings.
(iv) Supports the development of local building regulations that promote flood-resistant construction practices in urban Nigeria.

In conclusion, selecting appropriate wall materials such as concrete blocks or stabilized earth blocks can significantly improve the performance of residential buildings during floods, reducing repair costs, improving safety, and supporting long-term resilience (Douglas et al., 2010; Hall & Hoff, 2012; Neville, 2011).

VII. RECOMMENDATIONS

Based on the findings and discussion of this study on water-resistant wall systems in flood-prone residential buildings in Port Harcourt, several practical recommendations are made for homeowners, builders, and policy makers. These recommendations focus on material selection, design improvements, and policy development.

7.1 Suitable Wall Systems for Flood-Prone Areas
The study shows that concrete blocks offer the best performance in terms of water resistance, durability, and ease of repair after flooding. Therefore, concrete block walls should be prioritised in flood-prone areas.

Stabilised earth blocks (SEBs) can be considered as an alternative where moderate performance is acceptable, particularly for low-cost housing, provided that they are properly stabilised and treated to resist water penetration.

Sandcrete blocks and untreated laterite walls are not recommended unless additional protective measures are applied, as they are highly vulnerable to water damage and require frequent maintenance (Neville, 2011; Hall & Hoff, 2012).

7.2 Design Improvements (Damp-Proofing Strategies)
To further improve flood resilience, buildings should incorporate simple design measures, such as:
1. Damp-Proof Courses (DPC): Installing DPC at the base of walls to prevent capillary rise of water from flooded ground.
2. Waterproof Coatings: Applying water-resistant paints or coatings to external walls to reduce water absorption.
3. Elevated Foundations: Raising floor levels above expected flood height to minimize direct water contact with walls.
4. Proper Plastering: Using cement-based or water-repellent plaster to protect masonry surfaces from moisture ingress.
5. Good Drainage: Ensuring proper site drainage to reduce water pooling around buildings (Douglas et al., 2010).

These improvements can significantly reduce structural damage, improve durability, and reduce recovery costs after flooding.

7.3 Policy Recommendations for Building Codes in Nigeria
To support long-term flood resilience, building codes and regulations in Nigeria should:
1. Promote Flood-Resistant Materials: Encourage the use of concrete blocks, stabilized earth

blocks, and other water-resistant materials in flood-prone regions.

2. Mandate Damp-Proofing: Include damp-proof courses, waterproof coatings, and other water-resistant features as mandatory for residential buildings in high-risk areas.
3. Establish Construction Guidelines: Develop clear guidelines for builders on proper masonry techniques, curing, and material stabilization to ensure high-quality construction.
4. Community Awareness: Educate residents and builders about flood-resilient design practices to reduce vulnerability and enhance safety.

By integrating these recommendations, Nigeria can improve the resilience of residential buildings, reduce economic losses, and protect the health and safety of flood-affected communities (Adelekan, 2010; Adebayo et al., 2018).

VIII. LIMITATIONS OF THE STUDY

While this study provides valuable insights into the performance of water-resistant wall systems in flood-prone residential buildings in Port Harcourt, there are some limitations that should be considered when interpreting the findings.

8.1 Sample Size Constraints

The study focused on a limited number of residential buildings within selected flood-prone neighbourhoods, specifically Eneka, Rukpokwu, and Eliozu. Although the buildings were purposively selected to reflect common wall systems in the area, the sample size may not fully represent all residential buildings in Port Harcourt or other parts of the Niger Delta region. As a result, caution is required when generalizing the findings to the wider population (Etikan et al., 2016).

8.2 Limited Laboratory Testing

Material testing, including water absorption and compressive strength after water exposure, was conducted on a restricted number of wall samples due to resource and time constraints. While these tests provided useful information on material performance, a larger and more diverse set of samples would provide more robust and statistically significant results. Additionally, other advanced laboratory tests, such as long-term durability under cyclic wetting and drying, were not included but could further enhance the understanding of material behaviour (Neville, 2011; Hall & Hoff, 2012).

Implications of Limitations

These limitations suggest that while the study offers meaningful insights into wall system performance in flood-prone areas, further research with larger sample sizes and more comprehensive laboratory testing is recommended to strengthen and validate the findings. Future studies could also explore other building components such as floors and roofs, as well as the effect of different construction techniques on flood resilience.

IX. SUGGESTIONS FOR FURTHER RESEARCH

While this study has provided useful insights into the performance of water-resistant wall systems in flood-prone residential buildings in Port Harcourt, further research is needed to expand understanding and improve flood-resilient housing strategies.

9.1 Long-Term Performance Studies

Future research should focus on long-term monitoring of wall systems under repeated flooding events. This will help to understand how materials perform over several years, including their durability, maintenance requirements, and resistance to moisture-related degradation. Long-term studies would also provide more accurate data on recovery costs and structural integrity over time, which is essential for designing sustainable and resilient residential buildings (Douglas et al., 2010; Neville, 2011).

9.2 Integration with Other Building Components

It is recommended that future studies examine the performance of wall systems in combination with other building components, such as floors, foundations, and roofs. Flooding affects entire structures, and understanding the interaction between walls, foundations, and floors is critical for holistic building resilience. For example, elevated foundations and damp-proofed floors may reduce water exposure to walls, thereby enhancing overall performance. Studying these interactions can inform more comprehensive flood-resilient design strategies (Hall & Hoff, 2012).

9.3 Additional Recommendations for Research Scope

(i) Explore the cost-benefit analysis of using different wall systems in flood-prone areas.
(ii) Investigate local construction practices and how they influence material performance under flood conditions.
(iii) Study alternative materials or innovative construction methods that could improve water resistance while remaining affordable for low-income residents.

By addressing these areas, future research can provide more detailed guidelines for designing, constructing, and maintaining flood-resilient residential buildings in Nigeria and other tropical regions at risk of flooding.

REFERENCES

[1] Adebayo, W. O., Oduwaye, L., & Olajide, O. (2018). Flood risk and vulnerability in Nigerian cities. Journal of Environmental Studies, 12(2), 45–59.

[2] Adeola, O. K., & Peters, O. R. (2025). Assessment of sustainable flood resilient housing: A review. International Journal of Research and Scientific Innovation.

[3] Adam, E. A., & Agib, A. R. A. (2001). Compressed stabilised earth block manufacture in Sudan. UNESCO.

[4] Adelekan, I. O. (2010). Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria. Environment and Urbanization, 22(2), 433–450.

[5] Ameh, H., Badarnah, L., & Lamond, J. (2024). Amphibious architecture: A biomimetic design approach to flood resilience. Sustainability, 16(3), 1069.

[6] Creswell, J. W., & Creswell, J. D. (2018). Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.). SAGE Publications.

[7] DEFRA. (2018). Improving the flood performance of new buildings. Department for Environment, Food & Rural Affairs, UK.

[8] Douglas, I., Garvin, S., Lawson, N., Richards, J., & Tippett, J. (2010). Urban pluvial flooding: A qualitative case study of cause, effect and nonstructural mitigation. Journal of Flood Risk Management, 3(2), 112–125.

[9] Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. American Journal of Theoretical and Applied Statistics, 5(1), 1–4.

[10] Field, A. (2013). Discovering statistics using IBM SPSS statistics (4th ed.). SAGE Publications.

[11] Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. Global Environmental Change, 16(3), 253–267.

[12] Hall, C., & Hoff, W. D. (2012). Water transport in brick, stone and concrete. CRC Press.

[13] Kelman, I. (2007). Physical flood vulnerability of residential properties in coastal, eastern England. Journal of Flood Risk Management, 1(2), 107–118.

[14] Lawson, T., et al. (2025). The impact of perennial pluvial flooding on the architectural quality and performance of residential buildings in selected areas of Port Harcourt metropolis. World Journal of Innovative Management and Technology, 9(2), 128–159.

[15] Mabrouk, M., Han, H., Mahran, M. G. N., Abdrabo, K. I., & Yousry, A. (2024). Revisiting urban resilience: A systematic review of multiple scale urban form indicators in flood resilience assessment. Sustainability, 16(12), 5076.

[16] Neville, A. M. (2011). Properties of concrete (5th ed.). Pearson.

[17] Olotuah, A. O. (2002). Recourse to earth for low-cost housing in Nigeria. Building and Environment, 37(1), 123–129.

[18] Preiser, W. F. E., & Vischer, J. C. (2005). Assessing building performance. Elsevier.

[19] Raheem, A. A., Momoh, A. K., & Soyingbe, A. A. (2012). Comparative analysis of sandcrete hollow blocks and laterite interlocking blocks. International Journal of Sustainable

© APR 2026 | IRE Journals | Volume 9 Issue 10 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I10-1716889

Construction Engineering & Technology, 3(1), 79–88.

[20] Wang, X., Nguyen, V. T. V., Zhou, X., & Najafi, M. R. (2024). Editorial: Building flood resilience under climate change. Frontiers in Environmental Science.