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Passive Design Fire Protection in High-Rise Residential Buildings: Challenges and Strategies for Sustainable Implementation in Abuja, Nigeria

Oaikhena, O. H.; & Akande, O. K.
Department of Architecture, Federal University of Technology Minna, Niger State, Nigeria.

Abstract
In Nigeria, high-rise residential buildings are increasing due to land scarcity driven by escalating prices and population growth. This is in addition to the need to grapple with critical fire safety challenges with over 7,000 annual fire outbreaks. This research delves into Abuja's high-rises, aiming to comprehensively assess passive fire protection measures' benefits, challenges, and strategies for long-term implementation. By deploying quantitative methods, 250 questionnaires were shared with building occupants, of which 213 responded, resulting in a remarkable 86% response rate and high data reliability (0.946). Notably, the findings underscore the pivotal role of specific passive design elements—like compartmentalization, fire-resistant materials, and evacuation components—in fostering safer living environments within the building. Challenges such as the lack of building fire safety compliance (0.881) and insufficient awareness (0.876) regarding passive design fire protection strategies were identified by the building occupants. This highlights the pressing need for tailored guidelines and enhanced stakeholder education. This research underscores the critical role of passive fire protection in addressing fire safety challenges in Abuja's high-rise residential buildings. It accentuates the urgent need for tailored guidelines, enhanced awareness, and comprehensive stakeholder education, emphasising the potential for enhanced safety and a resilient urban environment and prioritising the well-being of occupants and stakeholders in Abuja. The paper concludes by advocating for a balanced approach, emphasising the synergy between innovative design, regulatory compliance, and pragmatic solutions to create safer and more resilient urban living environments.

Keywords: Fire Protection, High-Rise Residential Buildings, Passive Design, Strategies of Implementation, Nigeria.

Introduction
Global urbanization is swiftly escalating, particularly in regions like South Asia and Sub-Saharan Africa, foreseen to surpass historical records by 2030 (World Bank, 2016; United Nations, 2019). However, this rapid urban expansion brings a host of challenges such as resource strain, congestion, and housing shortages (UN Habitat, 2017; Kuddus *et al*. 2020i, 2020). As a response to the pressing need for space, high-rise residential buildings are increasingly prevalent due to escalating land prices and population growth (Smith, 2020; Olanrewaju *et al.,* 2014; Kavilkar & Patil, 2014). Yet, while high-rise constructions offer solutions to land scarcity, they come with unique challenges, particularly concerning fire safety (NFPA, 2016). In the dynamic landscape of cities like Abuja, Nigeria's capital, rapid urbanization and soaring land prices are driving the proliferation of towering structures. These buildings serve the burgeoning population but raise concerns about fire risks and psychological impacts (Charlterjee, 2009; Zahari *et al.,* 2014).

Studies have underscored the heightened fire risk due to the vertical nature of these constructions (Abdullah, 2011; Lantz & Skroder, 2013), as well as potential challenges in evacuation (Gifford & Lacombe, 2007). Recent fire incidents have amplified the urgency of addressing fire safety specifically in these high-rise structures (Nimlyat *et al.,* 2017; Nwaichi *et al.,* 2023). Consequently, there's a growing emphasis on passive

fire protection strategies. These integral safety measures aim to automatically impede fire and smoke spread, ensuring safe evacuation routes and property safeguarding. Given the ongoing surge in urbanization, the enhancement of these strategies within high-rise constructions becomes pivotal. In developing nations, fire disasters present a significant challenge, with millions of incidents and numerous fatalities recorded globally (Agbola & Falola, 2021; Salazar *et al.,* 2021; Brushlinsky *et al*., 2016; Brushlinsky *et al*., 2022).

Nigeria alone reports over 7,000 annual fire outbreaks, causing substantial human and financial losses (Wakili, 2013; Nimlyat *et al*., 2017). Abuja's high-rise residential landscape faces critical fire vulnerability due to inadequate active fire protection (Obasa *et al.,* 2020). Despite global emphasis on passive fire protection in high-rises, its practical implementation in Abuja lacks tailored adaptation and clear guidelines, hindering seamless adoption. This research aims to comprehensively assess the challenges, benefits and strategies of implementing passive fire protection in Abuja's high-rise residential buildings, focusing on safety enhancement, fire risk reduction, and urban development optimization.

Literature review

The theoretical basis supporting high-rise development in cities like Nigeria revolves around the compact city model (Williams, 2003; Iderlina, 2010; Salingarous, 2006). This model promotes upward and inward development, reducing urban sprawl and fostering sustainability by optimizing infrastructure and services. High-rise apartment buildings in Nigeria have a history dating back several decades, with government-initiated developments like Eric Moore Towers and the 1004 Estate in Lagos (Olanrele *et al*., 2014). Public and private initiatives, including structures like Niger Tower and Folawiyo Tower in Lagos, and the World Trade Residential Towers in Abuja, signify the increasing trend of high-rise construction in the country. High-rise buildings, especially those with mixed-use functions, face escalated fire risks, when mixed occupancies are combined, these structures become more fire-vulnerable due to the diversity of activities and materials housed within (Ahmed *et al*., 2021). This fire risk is influenced by factors such as building positioning, height, means of egress, and the unique design of their atrium or courtyards (Ahmed *et al*., 2021).

The positioning of a building is pivotal; minimal setbacks in surrounding plots or limited front road access can exacerbate fire hazards. Building height, surpassing recommended limits, can impede fire service accessibility and complicate evacuation efforts. Moreover, the size, shape, and orientation of an atrium within these structures can intensify fire risks, with opened atria or courtyard posing potential pathways for fire propagation (Ahmed *et al.,* 2021). Atriums and courtyards within these structures further exacerbate the stack effect, creating vertical pathways for fire and smoke propagation, thereby complicating evacuation procedures and firefighting efforts (Miller & Taylor, 2018; Wilson & Brown, 2020). In high-rise buildings, the stack effect emerges as a defining factor in fire behavior, driven by temperature and pressure differentials that influence smoke movement and evacuation dynamics (Lee & Nguyen, 2017; Wang *et al*., 2021). Understanding these multifaceted influences is paramount for developing comprehensive fire safety strategies and enhancing building resilience in the face of fire hazards (Doe & Smith, 2022; Johnson *et al.,* 2023).

Passive Fire Protection (PFP) stands as an indispensable mechanism within structures, purposefully designed to impede the rapid spread of fire. It plays a pivotal role in safeguarding occupants by granting crucial time for safe evacuation and supporting firefighters in effectively managing fires. Unlike active fire systems reliant on human intervention, PFP operates autonomously, seamlessly integrated into a building's structural framework (Arewa *et al*., 2021). These multifaceted PFP measures are guided by several foundational principles meticulously crafted to mitigate fire hazards comprehensively. They encompass fire containment, utilizing fire-resistant elements like walls and doors to halt the spread of fire and smoke. Compartmentalization techniques segment buildings into fire zones, curbing fire expansion and limiting its reach. Ensuring structural integrity becomes paramount to withstand fire stress and prevent structural collapse, while regulating smoke movement aids in creating clearer evacuation pathways. Furthermore, robust fire-resistant systems endure fire impacts, facilitating safe evacuation, and strict adherence to building codes to uphold safety standards is imperative (Kurniawan *et al*., 2018).

Local building codes and regulations serve as guidelines governing building design and construction concerning fire safety (David et al., 2019). These regulations typically fall into two categories: passive fire control systems and active fire control systems (Barnett, 2002). They emphasize avoidance of fire risks, assessment of unavoidable risks, and combating identified risks at the point of ignition (Fire Safety Code, 2013; National Building Code, 2006;

NFPA, 2008). Passive fire control focuses on design elements such as escape routes, compartmentation, and access for firefighters (David et al., 2019). Codes like the (Nigeria Fire Safety Code, 2013) and (National Building Code, 2006) outline safety provisions like emergency vehicle access, designated assembly points, and firefighting equipment access (White, 2002). Ensuring adequate width and obstruction-free escape stairs is crucial to facilitate safe evacuation during emergencies (Nachtigall, 2017). The Nigerian National Building Code 2006 details regulations on compartmentation, materials, and means of egress (NNBC, 2006). Conversely, active fire control systems, encompassing sprinklers, smoke detectors, extinguishers, and alarms, are crucial for fire suppression (NFPA, 2008). The National Building Code stipulates requirements for sprinkler systems, smoke control, and fire alarms in tall buildings, emphasizing both manual and automatic fire control measures (NNBC, 2006).

Research methodology

The methodology chapter serves as a methodological blueprint for the comprehensive investigation into this study. The research design employs quantitative methodology to comprehensively investigate the subject matter. The research approach combines deductive and inductive approaches to address specific objectives, ensuring a systematic investigation of specific aspects while accommodating the complexities inherent in identifying challenges and formulating recommendations. Variables in the study include the extent of passive fire protection measures, occupants' awareness and safety perception, effectiveness of passive fire protection measures, challenges faced by professionals, building characteristics, compliance with local building codes and regulations, response and evacuation procedures, and resident demographics. The questionnaire surveys employ closed-ended questions to streamline the analysis of responses, with careful consideration given to question simplicity to prevent respondent disengagement.

Building selection criteria

A purposive sampling method was employed in selecting specific high-rise residential buildings (Table 3.1) in Lagos and Abuja based on criteria such as occupancy type (residential) and number of floors (15- 40 floors). A total of 250 questionnaires were distributed among building occupants in these selected buildings who were chosen at random, resulting in an 86% response rate, with 213 properly filled out questionnaires returned and utilized for analysis. This sampling strategy aimed to provide a broad and representative sample, contributing to the generalizability and applicability of the study's conclusions across diverse contexts.

Table 3.1: Buildings selected

S/N	Name	N0. of suspended floors	Units
1	WTC residential tower, Abuja	24	120
2	Eko champagne pearl tower, Lagos	33	60
3	4 Bourdilllon apartment, Lagos.	25	41
4	Eden height tower, Victoria Island, Lagos	15	27
	Eko court tower, Victoria Island, Lagos	24	155

Data analysis in this study involves descriptive and inferential statistics, with reliability and validity tests conducted to ensure the quality of measurements. Descriptive statistics was used to summarize the features of the dataset, while inferential statistics aid in drawing conclusions and making predictions based on collected data, facilitating the identification of significant differences and correlations between variables.

Study area

The study was conducted within the Abuja metropolis in Nigeria, which spans an area of approximately 8,000km2 and is positioned between latitudes 8° 25’ 00” – 9° 20’ 00” North of the equator and longitudes 6° 45’ 00” – 7° 39’ 00” East of the Greenwich Meridian. With an altitude of 840 meters above sea level, Abuja serves as Nigeria's administrative capital and ranks as the fourth most populous city in the country. Abuja is structured into five phases—phase 1, phase 2, phase 3, phase 4, and phase 5—each comprising several districts. This study specifically focuses on phase 1 shown in fig. 3.1, known for its prestigious neighborhoods, luxurious estates, well-developed housing, advanced infrastructure, and towering residential buildings.

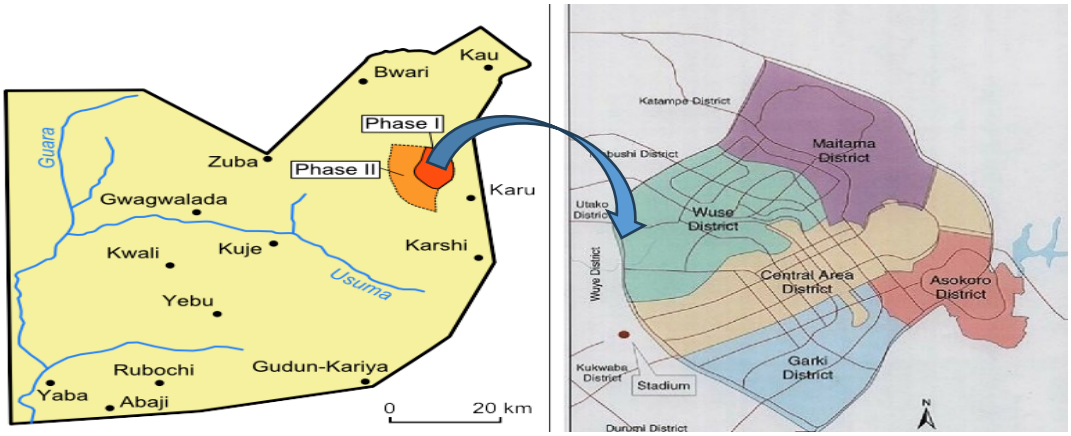


Fig. 3.1: map of F.C.T Abuja showing Phase 1
Source: Bohr, 2006. Adama, 2020.

Results and discussions

Reliability test

Table 4.2 provides reliability test results for different sections of the survey or questionnaire administered to respondents and professionals.

Tabel 4.2: Reliability test results

Section	Cases	Reliability test
Section B	5	0.850
Section C1	6	0.932
Section C2	6	0.947
Overall, for Respondent	17	0.946
Section D1	5	0.964
Section D 2	5	0.940
Section E	11	0.913
Section F	8	0.899
Overall for the Professionals	29	0.938

In Section B, there were 5 cases analyzed with a reliability test score of 0.850, indicating a moderate level of reliability. For Section C1, C2, and the overall respondent group, consisting of 17 cases in total, reliability scores were notably higher, ranging from 0.932 to 0.946, suggesting a high level of reliability in the responses provided. Similarly, for Sections D1, D2, E, and F, along with the overall professional group consisting of 29 cases, reliability scores were generally high, ranging from 0.899 to 0.964, indicating a high level of reliability in the data collected from these sections. Overall, the reliability test scores for both respondent and professional groups suggest that the survey or questionnaire yielded consistent and reliable responses across different sections, enhancing the validity of the data collected.

Demographic information

Table 4.3 shows the collected data showcases a varied demographic participation, predominantly from the 18-34 age group, comprising around 63% of respondents. This signals a strong interest or engagement among younger individuals in the subject matter. Despite this, the survey presents a well-distributed representation across age brackets, indicating a diverse range of perspectives. In terms of gender, the survey demonstrates a relatively balanced ratio, slightly skewed towards male respondents.

Table 4.3: Respondents demographic data information

Variables	**Frequency**	**Percentage**
Age		
18-24	56	26.3
25-34	7 8	36.6
35-44	35	16.4

45-54	22	10.3
55-64	12	5.6
65 and above	10	4.7
Gender		
Male	116	54.5
Female	97	45.5
Educational Level	1	0.5
Primary education	20	9.4
Secondary Education	7	3.3
Vocational education	125	58.7
Graduate degree	60	28.2
Post-graduate degree		
Disabilities		
Yes	7	3.3
No	206	96.7

Moreover, the educational background of participants primarily leans towards higher education, with approximately 87% possessing graduate or post-graduate degrees. This suggests a cohort predominantly composed of educated or specialized individuals, potentially professionals within the field under scrutiny. The data also indicates a minority representation with basic educational levels, highlighting a focus on engaging individuals with more advanced educational backgrounds. Overall, the findings reflect an engaged, educated, and somewhat youthful audience, providing insights primarily from those with higher qualifications and spanning various age groups.

Awareness of passive fire protection strategies

In figure 4.2, the result shows that about 33.3% of respondents can recognize PFP measures, with 37.1% being very aware and 8.5% not very aware. A mean value of 3.83 suggests overall awareness among respondents. Roughly 32.4% are aware of building division with fire-resistant barriers. 30% are very aware, while 9.4% are not very aware. The mean value of 3.6 indicates moderate awareness.

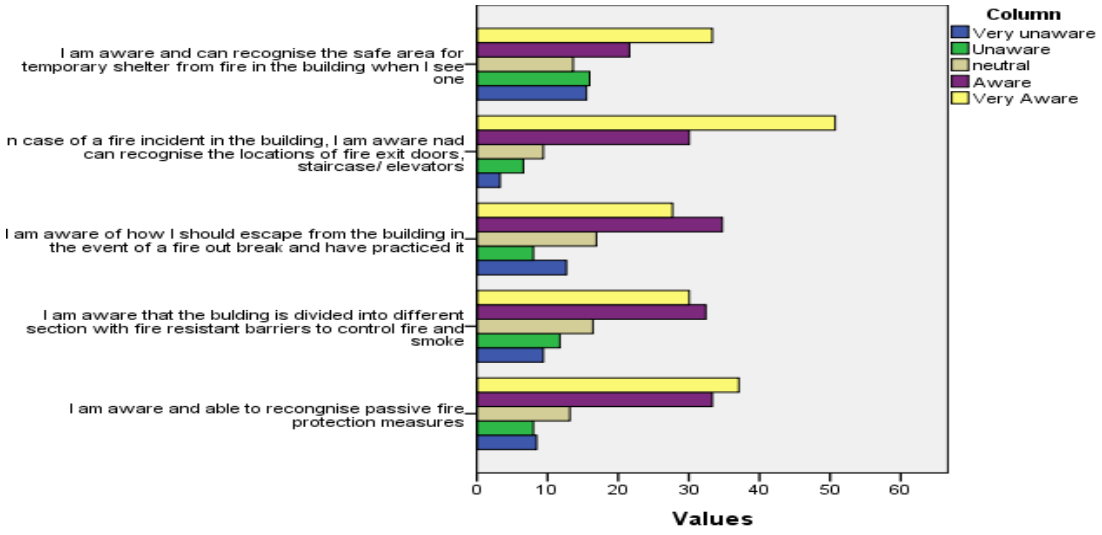


Figure 4.2: bar chart showing respondents' awareness of passive fire protection measures

Around 34.7% know how to escape during a fire outbreak, with 27.7% being very aware and 12.7% not very aware. The mean value of 3.57 suggests awareness and practice among respondents. Approximately 30% can recognize fire exit locations, while a significant 50.7% are very aware. Only 3.3% are not very aware, with a mean value of 4.18, indicating strong recognition. About 21.6% can recognize safe areas for shelter during a fire, with 33.3% being very aware. However, 15.5% are not very aware, and 16% are not aware, indicating less awareness in this

aspect. The mean value of 3.41 suggests neutrality among respondents regarding this subject. Overall, the data indicates a moderate to high level of awareness among the respondents regarding passive fire protection measures. Across various aspects such as recognizing PFP measures, understanding building division for fire control, knowing escape procedures, identifying fire exit locations, and awareness of safe shelter areas, the respondents showed a range of awareness levels. Overall, the mean values and percentages suggest a considerable awareness among the respondents, particularly in recognizing fire exit locations (with a mean value of 4.18) and escape procedures (with a mean value of 3.57).

Benefits of passive fire protection measures

In figure 4.3, the majority of respondents showed positive safety perceptions regarding various passive fire protection (PFP) measures in high-rise buildings in Abuja.

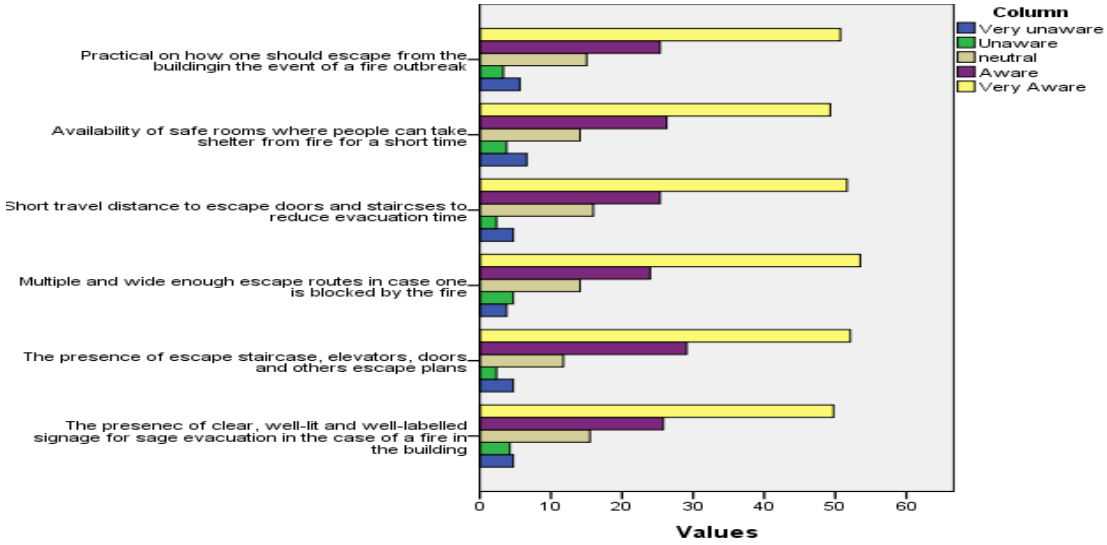


Figure 4.3: Respondents' perceptions regarding various passive fire protection measures under egress/evacuation strategy

Approximately 49.3% to 53.5% of participants indicated safety or strong safety agreement for different PFP features like well-labelled evacuation signs, escape plans, multiple wide escape routes, short travel distances to exits, availability of safe rooms, and practical escape guidance in case of fire incidents. The mean values ranged around 4.08 to 4.22, reflecting an overall inclination towards perceiving these PFP measures as safe or very safe. This suggests a variance in the understanding and confidence levels regarding the effectiveness of passive fire protection strategies, highlighting the need for improved education and awareness campaigns to ensure a more uniform understanding of their safety benefits. The interpretation of this data collected highlights several key points that relate to the benefits of such measures. Firstly, the positive safety perceptions expressed by the majority of respondents indicate that passive fire protection measures are seen as effective in enhancing safety within high-rise buildings. This aligns with the intended benefits of PFP measures, which aim to mitigate fire hazards and provide safer environments for occupants.

The specific features of PFP measures mentioned by respondents, such as well-labelled evacuation signs, escape plans, multiple wide escape routes, short travel distances to exits, availability of safe rooms, and practical escape guidance, correspond to known benefits of these measures. These features contribute to improved evacuation procedures, reduced evacuation times, and increased chances of safe egress during fire incidents. Additionally, the mixed perception of safety among respondents regarding certain PFP measures underscores the importance of continuous improvement and refinement of these measures. While some respondent's express confidence in measures like dividing buildings, using fire-resistant materials, smoke control systems, early hazard management, proper installation of protection measures, and regular maintenance, others remain neutral or skeptical. This suggests that there may be areas where further enhancements or clarifications are needed to fully realize the benefits of these measures and address any lingering doubts or concerns. Overall, the interpretation of respondents' safety perceptions emphasizes the importance of passive fire protection measures in high-rise buildings and underscores the ongoing need for education, awareness campaigns, and continuous improvement efforts to ensure that these measures are effectively implemented and widely recognized for their safety benefits.

In figure 4.4 respondents' perceptions regarding various passive fire protection measures under fire resistant materials and construction were gauged. Results revealed that 9.3% considered dividing buildings into sections with fire doors and firewalls as very safe during fire outbreaks, with an additional 30.5% expressing it as safe. Fire-resistant materials for preventing rapid fire spread garnered 48.8% agreement as very safe, followed by 19.1% considering them safe. Smoke control systems, such as smoke and fire dampers, were perceived as very safe by 53.5% of respondents, while early steps to manage potential fire hazards, like regular electrical system inspections, were deemed very safe by 55.4%. Proper installation of passive fire protection measures received 53.4% agreement as very safe, and regular building maintenance for fire safety was viewed as very safe by 57.3% of respondents. However, varying percentages also identified some measures as neutral, unsafe, or very unsafe, indicating diverse perceptions of safety across these passive fire protection strategies. The overwhelming agreement among respondents regarding the safety of various Passive Fire Protection (PFP) measures directly implies their perceived benefits. The positive perception of features such as clear evacuation signage, well-planned escape routes, fire-resistant materials, smoke control systems, early hazard management, and proper installation of protection measures highlights the acknowledged advantages of these strategies.

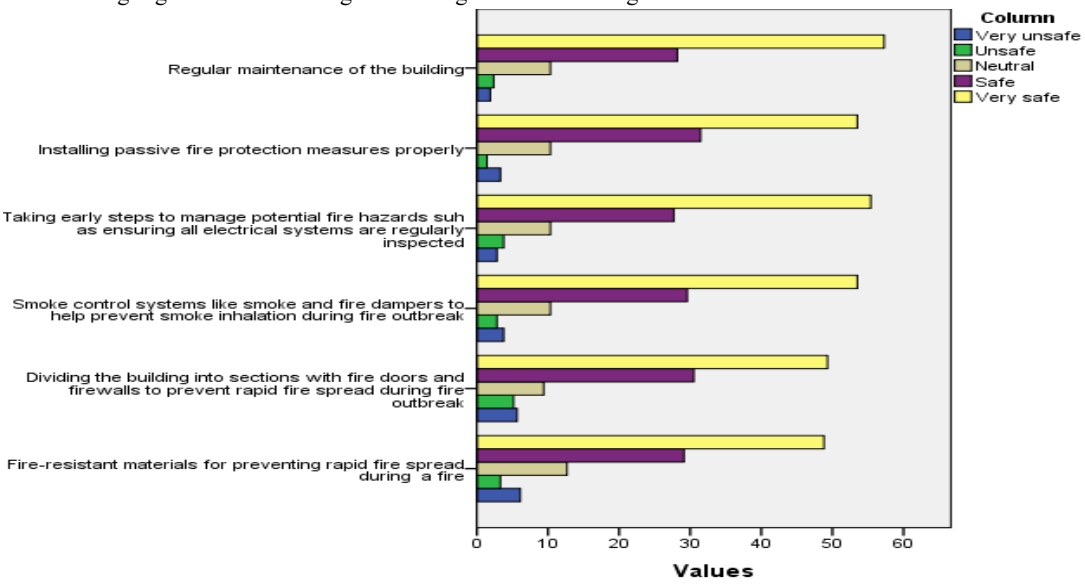


Figure 4.4: Respondents' perceptions regarding various passive fire protection measures under fire resistant materials and construction

This collective agreement strongly suggests that these PFP measures are seen as effective tools in enhancing safety, minimizing risks, and ensuring better fire incident management within buildings. The consensus on their safety underscores their perceived role in safeguarding lives, reducing fire-related dangers, and promoting a secure environment during emergencies.

Building professional back ground information.

Table 4.4 shows that the majority of respondents possess qualifications as Registered Architects and Engineers, making up a significant portion of the sample. Professionals with specific certifications in fire safety or protection constitute a smaller percentage of the respondents. A notable proportion of respondents (21.6%) fall under a General Consultant License category, indicating a diverse range of expertise. In terms of experience, a significant percentage of respondents have between 0-10 years of experience, suggesting a considerable presence of relatively newer professionals in the field. However, a substantial number also have more than 10 years of experience, demonstrating a balanced mix of both seasoned and newer professionals participating in the study.

Table 4.4: Building professional back ground information.

Variable	Frequency	Percentage
Professional qualification		
Registered Architect	21	28.4
Registered Engineer	18	24.3
Certified fire safety engineer	12	16.2
Certified fire safety consultant	1	1.4

Certified fire protection specialist	1	1.4
General Consultant license	16	21.6
Others	5	6.8
Years of experience		
0-5	23	31.1
6-10	24	32.4
11-15	9	12.2
16-20	5	6.8
20 and above	13	17.6

Challenges faced by the professionals while implementing the passive fire protection measures

Relative Important index was used to identify the challenges faced by the professionals while implementing the passive fire protection measures. Accoding to (Oyedele, 2018) the Relative Important index formular is given as:

$$RII = \frac{\sum W}{A * N}$$

Where W= Weight given to each statement by the respondent

A=Highest response integer which is 5

N= Total number of professionals=74

Findings from Table 4.5 the first and major challenge identify by the professional professionals while implementing the passive fire protection measure is the issues with fire safety regulations and compliance while the second challenge identified is the lack of awareness and knowledge about passive fire protection strategies, poor project management is rank as the third challenge faced by the professionals, insufficient communication and training for building occupant, maintenance and inspection difficulties and lack of coordination among professionals involved in the construction process are identified as the 4th, 5th and 6th challenges faced by the professionals while implementing the passive fire protection measures while inadequate budget or funding for effective fire protective measures, issues with retrofitting fire protection measures in existing buildings and resistance to adopting new fire protection techniques are identified as the 9th, 10th and 11th (least) challenges faced by the professionals while implementing the passive fire protection measures.

Table 4.5: Challenges of implementing passive fire protection measures by building professionals

Challenges	SD	D	N	A	SA	$\sum W$	RII	Rank
Lack of awareness and knowledge about passive fire protection strategies	2 (2.7)	2(2.7)	5(6.8)	22(29.7)	43(58.1)	324	0.876	2
Inadequate budget or funding for effective fire protective measures	4 (5.4)	7(9.5)	2(2.7)	27(36.5)	34(45.9)	302	0.816	9
Difficulty in obtaining fire resistant materials and products	2(2.7)	7(9.5)	7(9.5)	24(32.4)	34(45.9)	303	0.819	8
Issues with fire safety regulations and compliance	1(1.4)	3(4.1)	6(8.1)	19(25.7)	45(60.8)	326	0.881	1
Design and construction challenges in integrating fire protection features	3(4.1)	4(5.4)	7(9.5)	24(32.4)	36(48.7)	308	0.832	7

Maintenance and inspection difficulties	3(4.1)	3(4.1)	7(9.5)	24(32.4)	37(50)	311	0.841	5
Lack of coordination among professionals involved in the construction process	3(4.1)	3(4.1)	8(10.8)	24(32.4)	36(48.6)	309	0.835	6
Resistance to adopting new fire protection techniques	6(8.1)	7(9.5)	9(12.2)	20(27)	32(43.2)	287	0.776	11
Issues with retrofitting fire protection measures in existing buildings	3(4.1)	8(10.8)	9(12.2)	22(29.7)	32(43.2)	294	0.795	10
Insufficient communication and training for building occupant	2(2.7)	6(8.1)	3(4.1)	26(35.1)	37(50)	312	0.843	4
Poor project management	4(5.4)	3(4.1)	3(4.1)	19(25.7)	44(59.5)	315	0.851	3

SD= Strongly disagreed, D=Disagreed, N= Neutral, A= Agree, SA= Strongly agreed, RII= Relative important index, $\sum \boldsymbol{W}$= Total weight

Table 4.6 presents a comprehensive set of recommendations aimed at optimizing the design and construction of high-rise apartments to bolster passive fire protection strategies. Each recommendation is assessed based on its perceived importance, ranging from "Very Unimportant" to "Very Important," with corresponding percentages provided. Notably, the recommendations with the highest mean values underscore the critical role of regular maintenance and inspection programs, emphasizing their indispensable contribution to sustaining passive fire protection effectiveness.

Table 4.6: Optimizing the design and construction of high-rise apartments to enhance passive fire protection strategies.

Variables	V.I.	U	N	I	V.I	Mean value
Increased budged allocation for passive fire protection is essential to ensure building safety	1(1.4)	1(1.4)	4(5.4)	30(40.5)	38(51.4)	4.39
Improving awareness and education about passive fire protection measures is crucial for effective implementation	0	2(2.7)	2(2.7)	17(23)	53(71.6)	4.64
Efforts to streamline the procurement of fire-resistant materials need to be enhanced	0	2(2.7)	7(9.5)	28(37.8)	37(50)	4.35
Stricter adherence to fire regulations can improve overall building safety	1(1.4)	2(2.7)	4(5.4)	13(17.6)	54(73)	4.58

Collaboration and early planning among architects, engineers and fire safety experts can address design and construction issues	0	2(2.7)	4(5.4)	21(28.4)	47(63.5)	4.53
Regular maintenance and inspection programs are necessary to sustain passive fire protection effectiveness	1(1.4)	0	4(5.4)	10(13.5)	59(79.7)	4.7
Training and awareness programs should target all building stakeholders from builders to occupants	0	1(1.4)	3(4.1)	13(17.6)	57(77)	4.7
Retrofitting solutions should be made more accessible and affordable for existing structures	0	3(4.1)	7(9.5)	24(32.4)	40(54.1)	4.37

V.U.-- Very unimportant, U= Unimportant, N= Neutral, I= Important, V.I.= Very important, percentage in bracket

Additionally, the table highlights the paramount importance of training and awareness programs targeting all building stakeholders, indicative of the necessity for comprehensive educational initiatives. Furthermore, improving awareness and education about passive fire protection measures emerges as a vital aspect, underscoring the need for enhanced understanding and knowledge dissemination. The findings also emphasize the significance of stricter adherence to fire regulations, signalling the pivotal role of regulatory compliance in enhancing overall building safety. Moreover, collaboration and early planning among architects, engineers, and fire safety experts are identified as essential elements, highlighting the importance of coordinated efforts in addressing design and construction challenges. Other notable recommendations include increasing budget allocation for passive fire protection, streamlining procurement processes for fire-resistant materials, and making retrofitting solutions more accessible and affordable for existing structures. These findings offer valuable insights for policymakers, stakeholders, and professionals involved in fire safety management and urban development, emphasizing the multifaceted approach required to effectively enhance passive fire protection in high-rise buildings

Conclusion and recommendation

In conclusion, the research comprehensively assessed the implementation of passive fire protection in Abuja's high-rise buildings, with a focus on safety enhancement, fire risk reduction, and urban development. Through the examination of theoretical frameworks, fire dynamics, passive fire protection and Nigeria's building codes, critical insights into enhancing passive fire protection strategies have been identified. The findings underscore the importance of concerted efforts among stakeholders to address challenges and implement recommendations effectively. Moving forward, it is imperative to prioritize improving awareness, strengthening regulatory compliance, fostering collaboration among stakeholders, and ensuring adequate resources to safeguard high-rise buildings effectively. Despite the progress made, it's essential to acknowledge the existing limitations and the need for continuous improvement in passive fire protection measures.

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