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ADOPTION OF STEEL FRAME HOUSE DESIGN FOR BUILDING SUSTAINABILITY: ASSESSING ITS HIGH QUALITY AND LOW COST PREFAB IN BUILDING WAREHOUSES IN NIGERIA.

By

AKPORHONOR, Davidson Avwerosuoghene

And

AKWAOWO, Dianabasi Reuben
Department of Architecture
Akwa Ibom State Polytechnic
Ikot Osurua, Ikot Ekpene

ABSTRACT

This study examined the adoption of steel frame house design for building sustainability, assessing its high quality and low-cost prefabrication potential in warehouse construction in Nigeria. Descriptive survey design was adopted for this study. The study was carried out in Nigeria and the targeted population for the study comprised of all the architects, civil engineers, quantity surveyors and builders in Nigeria. A stratified sampling technique was used in selecting 15 Architects, 15 civil engineers, 15 quantity surveyors and 15 builders, each from 3 geographical zones in Nigeria (South-South, South- East and North-West). This gave a total sample size of 180 respondents. The instrument used for data collection was a structured questionnaire titled "Steel Frame House Design and Building Sustainability Questionnaire" (SFHDBSQ). Face and content validation of the instrument was carried out by an expert in test, measurement and evaluation in order to ensure that the instrument has the accuracy, appropriateness and completeness for the study under consideration. The reliability coefficient obtained was 0.89, and this was high enough to justify the use of the instrument. The researcher subjected the data generated for this study to appropriate statistical technique such as descriptive statistics to answer research questions and regression analysis to test the hypothesis. The R-Square value of 0.92 from the study predicts 93% of the extent to which steel frame house design influences tendencies of building sustainability in Nigeria. This rate of percentage is highly positive and therefore means that there is significant extent to which steel frame house design influences tendencies of building sustainability in Nigeria. The study concludes that steel frame house design offers a modern solution to Nigeria's construction challenges, including high costs, long timelines, and material inefficiency. One of the recommendations made was that the government of Nigeria should introduce supportive policies, tax incentives, and regulatory frameworks that encourage the adoption of steel frame prefabricated systems in industrial and warehouse construction.

KEYWORDS: Steel Frame House Design, Building Sustainability, High Quality, Low Cost Prefab, Warehouses, Nigeria

INTRODUCTION

The construction industry in Nigeria continues to experience challenges related to high construction costs, material wastage, extended project timelines, and concerns about long-term structural sustainability. With increasing urbanization and industrial growth, the demand for efficient warehouse facilities has risen significantly. Warehouses play a critical role in supporting trade, manufacturing, and logistics, yet conventional construction methods—primarily reinforced concrete and sandcrete block systems—often involve high labor intensity, longer construction periods, and increased overall project expenses. These limitations highlight the need for alternative building technologies that promote sustainability, cost-effectiveness, and high structural performance. Previous studies on sustainable construction practices in Nigeria emphasize the

importance of adopting innovative structural systems that enhance efficiency and environmental performance within the built environment (Usanga, 2021).

Steel frame house design, particularly through prefabricated (prefab) construction systems, has emerged globally as an innovative and sustainable building solution. Steel structures are widely recognized for their high strength-to-weight ratio, durability, resistance to fire and pests, and adaptability to large-span designs suitable for warehouses (Smith, 2018). Prefabrication enhances these benefits by enabling building components to be manufactured off-site under controlled conditions, thereby improving quality control, reducing material waste, and accelerating on-site assembly (Gibb, 1999). This method not only improves construction efficiency but also contributes to environmental sustainability through reduced site disturbance and optimized resource use.

In the Nigerian context, the adoption of steel frame prefab systems for warehouse construction presents a viable strategy for addressing both economic and environmental challenges. Steel frame structures provide flexible interior spaces without the need for excessive columns, making them particularly suitable for industrial and storage facilities. Additionally, their shorter construction period can significantly reduce labor costs and project delays, which are common in traditional building systems. However, despite these advantages, the adoption rate of steel frame house design in Nigeria remains relatively low due to factors such as limited technical expertise, higher perceived initial costs, and preference for conventional construction methods.

Therefore, this study seeks to assess the adoption of steel frame house design for building sustainability by examining its high-quality performance and low-cost prefabrication potential in warehouse construction in Nigeria. By evaluating its structural efficiency, economic viability, and sustainability benefits, this research aims to contribute to the growing body of knowledge on modern construction technologies and provide recommendations for improved implementation within the Nigerian building industry.

Statement of Problem

The increasing demand for warehouses in Nigeria has led to the need for building methods that are durable, cost-effective, and sustainable. However, many warehouse buildings still rely on traditional construction methods that often involve high costs, longer construction time, and material waste. Although steel frame house design offers high quality, strength, and the advantage of prefabrication, its adoption in warehouse construction in Nigeria remains relatively low. This limited adoption may be due to lack of awareness, technical knowledge, and perceived high initial cost. Consequently, the potential benefits of steel frame prefabricated structures for sustainable warehouse development are not fully utilized. Therefore, there is a need to assess the adoption of steel frame house design in terms of its quality and low-cost prefabrication in warehouse construction in Nigeria.

Objective of the Study

1. To find out the extent of steel frame use in warehouse building construction in Nigeria
2. To examine the effect of steel frame house design on building sustainability

Research Questions

1. What is the extent of steel frame use in warehouse building construction in Nigeria?
2. What is the effect of steel frame house design on building sustainability?

Hypotheses

1. **There is no significant effect of steel frame house design on building sustainability in Nigeria.**

LITERATURE REVIEW

Concept of Steel Frame

The term "steel frame" describes a basic building construction system in which a network of horizontal beams and vertical steel columns creates a skeleton framework that supports a building's floors, walls, and roofs while bearing structural loads. Compared to conventional load-bearing systems composed of masonry or timber, this method allowed for greater spans, taller structures, and quicker assembly, revolutionizing modern construction. The skyscraper era was preceded by the invention of steel frames, which are still essential to modern engineering and architectural design for various building types. Fundamentally, the steel frame system depends on the ductility and strength of steel, a material with a high strength-to-weight ratio that enables structures to effectively handle both vertical and lateral loads. Structural steel framing gives structures of all sizes stability and robustness by connecting steel elements, including I-beams, H-sections, and cold-formed members, to withstand bending, shear, and axial pressures. When appropriately constructed, modern steel frames can also have rigid or moment-resisting connections that increase lateral stiffness and improve performance under seismic or wind loads.

Light gauge steel framing (LGSF), a subset frequently utilized in residential, commercial, and mid-rise buildings, is an important development of steel framing. This technology allows for quick construction, better quality control, and less material waste by precisely manufacturing thin, cold-formed steel sections off-site and assembling them on-site. LGSF provides better dimensional precision, design flexibility, and interoperability with cutting-edge digital technologies like Building Information Modeling (BIM), which improves coordination, lowers errors, and speeds up project delivery when compared to timber or masonry (Bussell, 2008).

Steel's recyclable nature and potential for high recycled content make steel frame sustainable and in line with current environmental concerns. Steel supports the ideas of the circular economy and reduces the need for primary raw materials because it can be reused indefinitely without suffering major degradation. The endurance of steel frames results in less maintenance throughout the building lifecycle, and precision manufacture also minimizes waste on-site. Additionally, steel frames are strong and long-lasting by nature. They can be designed for improved fire resistance and environmental load performance, and they withstand frequent problems with traditional materials, like rot, termites, and warping. Because of these qualities, steel frames are appropriate for everything from major commercial projects to industrial facilities and residential homes, offering structural dependability and architectural flexibility.

Concept of Steel Frame House

A steel frame house refers to a residential building constructed using a structural framework made primarily of steel members such as columns, beams, and studs that support the load of the building. Instead of traditional materials like timber or reinforced concrete, the structural skeleton of the house is formed with steel components that are fabricated and assembled to create a strong and stable structure. Steel framing is often used in modern construction because of its high strength, durability, and ability to support flexible architectural designs (Oliveira &Sironi, 2022). Steel frame housing is the process where cold-formed steel

sections are used to form the structural framework of walls, floors, and roofs. These steel components are usually prefabricated in factories and later assembled on-site, which improves construction accuracy and reduces construction time. This method is increasingly adopted in modern housing projects because it promotes efficiency, minimizes material waste, and enhances structural stability compared with conventional brick or timber construction systems (Oliveira &Sironi, 2022).

Steel frame houses are defined as their strength-to-weight ratio, meaning that steel structures can support heavy loads while remaining relatively lightweight. This property allows the construction of wider spans, open floor layouts, and innovative architectural designs. In addition, steel does not warp, shrink, or twist like wood, ensuring long-term structural stability and reducing maintenance requirements (JG King Homes, 2024).

Concept behind steel frame housing is sustainability and environmental efficiency. Steel is one of the most recyclable materials in the construction industry, and many steel-frame houses incorporate recycled steel. This reduces environmental impact and promotes sustainable construction practices. Furthermore, steel frame systems often generate less construction waste and allow faster building processes, making them suitable for modern housing development and urban expansion (Metal Pro Buildings, 2024). the concept of a steel frame house centers on using a steel structural skeleton to support residential buildings, providing durability, design flexibility, faster construction, and environmental sustainability. As a result, steel framing has become an increasingly popular construction method in contemporary architecture and housing development.

Concept of Steel Frame House Design

Steel frame house design is a modern structural and architectural approach that uses steel framing systems as the primary load-bearing skeleton for residential buildings. Unlike traditional masonry or timber framing, steel frames consist of vertical columns and horizontal members that support floors, walls, and roofs, creating a durable and flexible residential structure. Steel framing originated in industrial and high-rise construction but has increasingly been adopted for single-family and multi-storey residential buildings due to its structural efficiency, design flexibility, and sustainable characteristics. Light gauge steel framing (LGSF) is a significant type of residential steel framing. Compared to conventional materials, this system offers a high strength-to-weight ratio and resistance to rot, termites, and fire tanks to the use of cold-formed, galvanized steel parts (such C-studs and U-tracks) that are manufactured to exact specifications. Because of these characteristics, LGSF is appropriate for both load-bearing and non-load-bearing residential walls. Additionally, this kind of frame makes it easier to prefabricate components off-site, which speeds up on-site assembly, enhances quality control, cuts waste, and shortens construction schedules (Narula, 2025).

Longer unsupported spans and open floor plans, which are becoming more and more popular in modern home design, are made possible by the higher stiffness and stability of steel frames. As long as the design and detailing follow the proper engineering standards, these structural advantages also increase resilience in areas vulnerable to severe wind or seismic loads. Steel's intrinsic strength allows for more creative freedom in architecture, supporting contemporary aesthetics like cantilevers, big windows, and simple shapes without sacrificing functionality. The design of steel frame homes is increasingly in line with sustainability objectives. One of the most recycled commodities in the world is steel, and cold-formed steel framing usually has a high recycled component. Prefabrication also lessens the impact of transportation and material waste which help to reduce the building's environmental impact over its lifetime. Steel-

framed homes can meet or beyond current energy standards with the help of efficient thermal and moisture-control details and renewable energy systems (Forsyth, 2007). Steel Frame House Design also highlights the role of modern construction technologies in improving long-term building performance and resource efficiency (Usanga, 2021)

Despite these benefits, designing a steel frame home has drawbacks, most notably thermal bridging because of the high thermal conductivity of steel. In order to satisfy comfort and energy-efficiency standards, steel stud wall designers must include thermal breaks and high-performance insulation. Furthermore, although while steel framing may initially cost more than conventional materials, its long-term performance and lower maintenance requirements frequently make it cost-effective. These developments underscore the evolving role of steel frame design in meeting both architectural and environmental imperatives, steel frame house design represents a flexible, resilient, and sustainable alternative to conventional residential construction. Its design concept integrates structural performance, architectural freedom, and environmental considerations, making it a compelling solution for contemporary housing needs worldwide.

Concept of Building Sustainability

The planning, design, construction, operation, and eventual demolition of buildings that reduce their detrimental effects on the environment, enhance social well-being, and ensure long-term economic viability are all considered aspects of building sustainability. In contemporary discourse (2020–present), the notion has broadened beyond energy efficiency to encompass occupant health, resilience, carbon neutrality, circular economy concepts, and intelligent technology integration.

Building sustainability is based on the triple bottom line framework, which includes social fairness, economic performance, and environmental preservation. Sustainable buildings aim to reduce greenhouse gas emissions, energy and water use, waste creation, and biodiversity.Decarbonization solutions, especially operational and embodied carbon reduction using life cycle assessment (LCA) approaches, are the focus of recent research (Pomponi&Moncaster, 2020; IPCC, 2022). While operational carbon is associated with emissions from energy use during building occupancy, embodied carbon includes emissions from resource extraction, manufacturing, transportation, and construction activities. According to studies, embodied carbon now makes up a sizable amount of lifetime emissions, particularly in energy-efficient buildings (Cabeza et al., 2021).

Sustainable building design still heavily relies on energy efficiency. Innovative architectural strategies such as biomimicry have also been identified as effective approaches to improving environmental performance and sustainable building outcomes (Usanga & Isaac, 2024).However, current developments center on net-zero energy buildings (NZEBs) and net-zero carbon buildings, using passive design techniques, high-performance envelopes, intelligent building management systems, and renewable energy technologies like solar photovoltaics (IEA, 2023). Building Information Modeling (BIM) and Internet of Things (IoT)-based monitoring systems are two examples of digital technologies that are being utilized more and more to optimize energy use and enhance performance tracking (Lu et al., 2020).

Resource efficiency and water conservation are also essential elements. To lower the demand for freshwater, sustainable buildings use low-flow fixtures, greywaterrecycling, rainwater harvesting systems, and sustainable drainage systems (UNEP, 2021). In order to decrease

demolition waste and increase building lifespans, the circular economy strategy also encourages material reuse, recycling, and adaptive reuse of buildings (Adams et al., 2022).

Social sustainability has gained popularity recently, especially after the COVID-19 epidemic. In order to improve occupant health and productivity, indoor environmental quality (IEQ), which includes air quality, thermal comfort, lighting, and acoustics, has gained importance (Allen et al., 2020). Green buildings are being evaluated according to their effects on human well-being and community resilience, in addition to environmental certifications like LEED and BREEAM.

Furthermore, climate resilience is a new pillar of building sustainability. Sustainable buildings are designed to withstand extreme weather, flooding, and temperature increases brought on by climate change. Flood-resistant materials, adaptable structural systems, and passive cooling are all integrated into resilient design (Aghimien et al., 2022).

Features of high quality of steel frame in warehouse buildings in Nigeria.

- **Structural Strength and Load-Bearing Capacity:**

High-quality steel frames in Nigerian warehouse buildings are primarily defined by their exceptional structural strength and ability to carry heavy loads. Warehouses typically accommodate bulk goods, machinery, and racking systems that impose significant dead and live loads on the structure. Structural steel, particularly when manufactured to international standards and properly engineered, provides the tensile strength and rigidity required for wide-span spaces without intermediate columns. This allows for efficient storage layouts and operational flexibility. Research shows that steel's high strength-to-weight ratio improves structural performance while reducing overall material usage compared to reinforced concrete in large-span industrial buildings (Landolfo, Cascini, & Portioli, 2017). In Nigeria's growing logistics and manufacturing sectors, adherence to quality steel standards ensures durability and compliance with modern structural codes (Adeleke & Olutoge, 2019).

- **Durability under Nigerian Climatic Conditions:**

Nigeria's diverse climate—ranging from coastal humidity in the south to high temperatures in the north—demands materials that can withstand corrosion, heat stress, and environmental degradation. High-quality steel frames are typically galvanized or coated with protective finishes that enhance resistance to rust and chemical exposure. When appropriate corrosion protection systems are applied, steel warehouse structures can maintain long service lives with minimal structural deterioration. Studies on steel performance in tropical environments highlight the importance of protective coatings and maintenance strategies in extending structural lifespan (Fajuyigbe & Saka, 2016). Properly treated structural steel demonstrates strong resilience against moisture-related damage, making it a reliable option for long-term warehouse infrastructure in Nigeria.

- **Speed and Precision of Construction:**

Another indicator of high-quality steel framing in Nigerian warehouse projects is the level of precision achieved through prefabrication and controlled fabrication processes. Structural steel components are often manufactured off-site under strict quality control conditions and then assembled on-site, reducing human error and improving dimensional accuracy. This precision enhances structural integrity and shortens construction timelines, which is crucial for commercial developments where time directly impacts profitability. Research indicates that prefabricated steel systems significantly improve construction efficiency and reduce project delays compared to

conventional building methods (Jaillon & Poon, 2016). In Nigeria's rapidly expanding industrial zones, this speed and accuracy contribute to both economic and operational sustainability.

- **Compliance with International Quality Standards:**

High-quality steel frames in Nigerian warehouses are often produced in compliance with international standards such as ASTM, BS EN, or ISO certifications. Compliance ensures consistency in chemical composition, tensile strength, weldability, and structural performance. Quality assurance processes, including non-destructive testing and certified welding procedures, further strengthen reliability. According to the World Steel Association (2018), adherence to standardized production practices enhances the safety and longevity of steel structures globally. For Nigerian construction projects, aligning with these standards improves investor confidence and ensures that warehouse facilities meet global safety and performance benchmarks (Oladokun & Proverbs, 2016).

- **Sustainability and Lifecycle Performance:**

High-quality steel framing also contributes to sustainability in Nigerian warehouse construction. Steel is highly recyclable, and many structural components contain significant recycled content, reducing embodied environmental impacts. Additionally, the adaptability of steel frames allows warehouses to be expanded or modified without complete demolition, extending building life cycles. Life cycle assessment studies confirm that durable steel structures with proper maintenance strategies can deliver long-term environmental and economic benefits (Pomponi & Moncaster, 2017). As Nigeria continues to industrialize, the integration of durable, recyclable steel framing in warehouse design supports sustainable infrastructure development while meeting the country's growing storage and logistics demands

Features of low cost prefab of steel frame in warehouse buildings in Nigeria.

- **Reduced Construction Time and Labor Costs:**

Low-cost prefabricated steel frame systems significantly reduce construction time for warehouse buildings in Nigeria, which directly lowers labor and project overhead costs. Because structural components are fabricated in controlled factory environments and delivered ready for assembly, on-site activities are streamlined and less dependent on prolonged manual work. This is particularly beneficial in Nigeria, where construction delays often increase expenses due to extended labor engagement and logistical challenges. Studies show that prefabrication can cut project timelines by 20–50%, resulting in substantial cost savings (Jaillon & Poon, 2016). Faster project completion also allows warehouse operators to begin commercial activities earlier, improving financial returns and overall economic efficiency.

- **Material Efficiency and Waste Reduction:**

Prefabricated steel framing enhances cost-effectiveness through precise material usage and minimal waste generation. Unlike traditional construction methods that often involve excessive material cutting and on-site adjustments, factory-based steel production follows standardized measurements and quality controls. This precision reduces off-cuts and unnecessary material procurement. Research indicates that industrialized building systems can significantly decrease construction waste compared to conventional methods, lowering disposal and material replacement costs. In Nigeria, where material transportation and waste management can be expensive, such efficiency contributes directly to making prefabricated steel warehouses more affordable.

- **Lower Foundation and Structural Costs:**

Steel's high strength-to-weight ratio makes prefabricated steel frames lighter than many conventional reinforced concrete systems. This reduced weight decreases foundation requirements, which are often a major cost component in warehouse construction. In regions of Nigeria with soft or variable soil conditions, lighter structures minimize excavation depth and foundation reinforcement needs. According to Landolfo, Cascini, and Portioli (2017), optimized steel structural systems can reduce overall material input while maintaining structural performance. These savings in both substructure and superstructure components make prefabricated steel framing an economically attractive option for large-span warehouse buildings.

- **Scalability and Design Flexibility:**

Low-cost prefabricated steel warehouses offer scalability, allowing businesses in Nigeria to expand storage capacity without demolishing existing structures. Modular steel components can be extended or modified with relatively minimal disruption, reducing long-term capital expenditure. This flexibility supports small and medium-sized enterprises that may need incremental expansion as operations grow. Research on modular construction emphasizes its cost benefits in terms of adaptability and reduced lifecycle expenses (Eberhardt, Birgisdóttir, & Birkved, 2019). By enabling phased development, prefabricated steel systems reduce the financial burden associated with large upfront investments.

- **Durability and Reduced Maintenance Expenses:**

Although initial cost is important, long-term affordability is equally critical. Prefabricated steel frames, when properly coated and protected against corrosion, demonstrate high durability in Nigeria's varied climatic conditions. Steel structures resist termites, rot, and warping—common issues affecting alternative building materials. This durability reduces frequent repair and replacement costs, contributing to lower lifecycle expenditure. The World Steel Association (2018) highlights that well-maintained steel buildings can maintain structural integrity for decades, enhancing economic sustainability. For Nigerian warehouse owners, reduced maintenance demands translate into predictable operating costs and improved return on investment.

Effect of steel frame house design on building sustainability

- **Reduced Material Consumption and Structural Efficiency:**

Steel frame house design enhances sustainability primarily through its high strength-to-weight ratio, which allows structural members to be slimmer and lighter while maintaining superior load-bearing capacity. This means fewer raw materials are required compared to many conventional systems, reducing resource extraction and associated environmental impacts. Because steel can span longer distances with less material, foundations can also be smaller, minimizing site disruption. Life cycle assessment studies show that optimized steel structural systems can reduce overall embodied impacts when efficient design strategies are applied (Gervasio & Dimova, 2018).

- **Recyclability and Circular Economy Contribution**

One of steel's strongest sustainability advantages lies in its recyclability. Steel used in house framing can be recycled repeatedly without significant loss of quality, making it central to circular construction models. Many steel-framed houses incorporate high percentages of recycled content, which significantly lowers embodied carbon compared to virgin production (World Steel Association, 2018). End-of-life recovery rates for structural steel are among the highest of any building material, reducing demolition waste and landfill pressure.

- **Energy Performance and Thermal Optimization:**

Although steel is highly conductive, thoughtful design strategies such as thermal breaks, insulated sheathing, and advanced wall assemblies can significantly improve the energy performance of steel-framed houses. Modern lightweight steel framing systems are engineered to limit thermal bridging and achieve compliance with strict energy codes (Santos, Martins & Simões, 2019). With proper detailing, these houses can reach low-energy or net-zero standards, particularly when integrated with high-performance windows and renewable energy systems. Studies indicate that optimized steel envelope systems can perform comparably to traditional construction in terms of operational energy use (Kesik & Saleff, 2016). Thus, design detailing plays a critical role in ensuring sustainability benefits are fully realized.

- **Construction Waste Reduction and Prefabrication Benefits:**

Steel frame house design often incorporates prefabrication and modular construction techniques, which substantially reduce material waste and improve resource efficiency. Factory-controlled production enhances precision, reducing off-cuts and on-site errors that commonly generate waste in traditional construction. Prefabrication also shortens construction time, lowering energy Cconsumption and emissions related to equipment and transportation. Research shows that industrialized steel building systems can reduce construction waste by up to 50% compared to conventional site-built methods (Jaillon & Poon, 2016). This efficiency contributes both to environmental sustainability and cost-effectiveness.

- **Durability and Resilience:**

Steel-framed houses are highly durable and resistant to termites, mold, warping, and fire damage, which enhances building longevity and reduces maintenance needs over time. Longevity is a key pillar of sustainability because longer-lasting structures reduce the frequency of replacement and resource consumption. Steel structures can also be engineered for high seismic and wind resistance, increasing resilience in disaster-prone regions (Landolfo Cascini, & Portioli, 2017). As extreme weather events increase in frequency, climate-resilient house design becomes more crucial. Steel framing supports the social and environmental aspects of sustainability by offering long-term performance and structural stability.

- **Embodied Carbon Considerations and Low-Carbon Innovations:**

While steel production is energy-intensive, technological advancements are steadily lowering its environmental footprint. Innovations such as electric arc furnace production using recycled scrap and emerging hydrogen-based steelmaking processes significantly reduce carbon emissions (International Energy Agency, 2020). When life cycle impacts are evaluated holistically, steel-framed housing with high recycled content and efficient design can achieve competitive embodied carbon levels (Pomponi & Moncaster, 2017). In order to maximize environmental benefits, carbon-conscious design choices and sustainable steel sources are essential. Low-carbon steel technologies are anticipated to considerably enhance the sustainability profile of steel frame homes as green building regulations become more prevalent worldwide.

METHODOLOGY

Descriptive survey design was adopted for this study. The study was carried out in Nigeria and the targeted population for the study comprised of all the architects, civil engineers, quantity surveyors and builders in Nigeria. A stratified sampling technique was used in selecting 15 Architects, 15 civil engineers, 15 quantity surveyors and 15 builders, each from 3 geographical zones in Nigeria (South-South, South- East and North-West). This gave a total sample size of 180

respondents. The instrument used for data collection was a structured questionnaire titled "Steel Frame House Design and Building Sustainability Questionnaire" (SFHDBSQ). Face and content validation of the instrument was carried out by an expert in test, measurement and evaluation in order to ensure that the instrument has the accuracy, appropriateness and completeness for the study under consideration. The reliability coefficient obtained was 0.89, and this was high enough to justify the use of the instrument. The researcher subjected the data generated for this study to appropriate statistical technique such as descriptive statistics to answer research questions and regression analysis to test the hypothesis.

RESULT AND DISCUSSION

Research Questions 1:

The research question examined the extent of steel frame use in warehouse building construction in Nigeria. To answer the research question percentage analysis was performed on the data, (see table 1).

Table 1:
Percentage Analysis of the Extent of Steel Frame Usage in Warehouse Building Construction in Nigeria

Extent	FRQ	%
VHE	21	11.67*
HE	43	23.89
LE	52	28.89
VLE	64	35.56**
TOTAL	180	100%

** The highest percentage frequency
* The least percentage frequency
SOURCE: Field survey

The above table 1presents the percentage analysis of the extent of steel frame usage in warehouse building construction in Nigeria. From the result of the data analysis, it was observed that the highest percentage (35.56%) of the respondents affirmed that the extent to which steel frame usage is adopted in warehouse building construction is of VERY LOW (VLE) in Nigeria, while the least percentage (11.67%) of the respondents affirmed that the extent is VERY HIGH (VLE).

Research Questions 2

The research question sought to examine the effect of steel frame house design on building sustainability. To answer the research question percentage analysis was performed on the data, (see table 2).

Table 2:
Percentage Analysis of the effect of steel frame house design on building sustainability

Effect of steel frame		FRQ	%
Reduced Material Consumption and Structural Efficiency		32	17.78
Recyclability and Circular Economy Contribution		24	13.33
Energy Performance and Thermal Optimization	36	20.00	
Construction Waste Reduction and Prefabrication Benefits	28	15.56	
Durability and Resilience		41	22.78**
Embodied Carbon Considerations and Low-Carbon Innovations	19	10.56*	
TOTAL	**180**	**100%**	

** The highest percentage frequency
* The least percentage frequency
SOURCE: Field survey

The above Table 2 presents the percentage analysis of the effect of steel frame house design on building sustainability. From the result of the data analysis, it was observed that the highest percentage (22.78%) was recorded against "durability and resilience", while the least percentage (10.56%) was recorded against "embodied carbon considerations and low-carbon innovations".

Hypothesis one

The null hypothesis states that there is no significant effect of steel frame house design on building sustainability in Nigeria. In order to answer the hypothesis, simple regression analysis was performed on the data (see table 3.)

TABLE 3: Simple Regression Analysis of the effect of steel frame house design on building sustainability in Nigeria

Model	R	R-Square	Adjusted R Square	Std. error of the Estimate	R Square Change
1	0.96a	0.92	0.92	0.411	0.92

*Significant at 0.05 level; df =178; N =180; critical r–value = 0.197

The above table 2 shows that the calculated R-value (0.96) was greater than the critical R-value of 0.197at 0.5 alpha levels with 178 degrees of freedom. The R-Square value of 0.92 predicts 93% of the extent to which steel frame house design influences tendencies of building sustainability in Nigeria. This rate of percentage is highly positive and therefore means that there is significant extent to which steel frame house design influences tendencies of building sustainability in Nigeria

Discussion of findings

The results of the data analysis in table 1 showed that the highest percentage (35.56%) of the respondents affirmed that the extent to which steel frame usage is adopted in warehouse building construction is of VERY LOW (VLE) in Nigeria. This suggests that even though steel frame is very potent in building construction and many people having recognized the significant role of steel framing in meeting the structural and functional demands of warehouse facilities across the

country many house owners are yet embrace this new innovation in the building industry. This finding agrees with the opinion of Landolfo, Cascini, & Portioli (2017), who stated that warehouses typically accommodate bulk goods, heavy machinery, and racking systems that impose substantial dead and live loads on the structure. They explained that structural steel, when manufactured to international standards and properly engineered, provides the tensile strength and rigidity required for wide-span spaces without the need for intermediate columns. According to them, steel's high strength-to-weight ratio enhances structural performance while reducing overall material consumption compared to reinforced concrete in large-span industrial buildings. Adeleke & Olutoge (2019) also affirm that with Nigeria's growing logistics and manufacturing sectors, adherence to quality steel standards ensures durability, safety, and compliance with modern structural codes. This therefore supports the respondents' view that steel framing is extensively and effectively utilized in warehouse building construction in Nigeria.

The results of the data analysis in Table 2 revealed that the majority of respondents affirmed that the effect of steel frame house design on building sustainability "durability and resilience". This finding agrees with the opinion of Santos, Martins & Simões (2019), who proved that although steel is highly conductive, thoughtful design strategies such as thermal breaks, insulated sheathing, and advanced wall assemblies can significantly improve the energy performance of steel-framed houses. They further explained that modern lightweight steel framing systems are engineered to limit thermal bridging and achieve compliance with strict energy codes. Kesik & Saleff (2016) also assert that with proper energy performance and thermal optimization, houses can reach low-energy or net-zero standards, particularly when integrated with high-performance windows and renewable energy systems. This therefore supports the view of the respondents that steel framing systems contribute significantly to building sustainability.

The results of the data analysis in Table 3 proved that the result was significant due to the fact that the calculated R-value (0.96) was greater than the critical R-value of 0.197 at 0.05 alpha level with 178 degrees of freedom. The result means that there is significant effect of steel frame house design on building sustainability in Nigeria. This result is in support of the findings of the International Energy Agency (2020), who noted that although steel production is energy-intensive, ongoing technological advancements are gradually reducing its environmental impact. Innovations such as electric arc furnace production using recycled scrap and emerging hydrogen-based steelmaking processes have been shown to significantly lower carbon emissions. Pomponi & Moncaster, (2017) also concur, emphasizing that when life cycle impacts are evaluated holistically, steel-framed housing with a high proportion of recycled content and efficient design can achieve competitive levels of embodied carbon. They further explain that low-carbon steel technologies are expected to substantially improve the sustainability profile of steel frame homes, particularly as green building regulations become increasingly widespread globally.

CONCLUSION

The adoption of steel frame house design offers a modern solution to Nigeria's construction challenges, including high costs, long timelines, and material inefficiency. Prefabricated steel systems provide high structural quality, durability, and flexibility, making them ideal for warehouse construction. They allow faster construction, reduce labor and maintenance costs, and minimize on-site material waste. Steel's recyclability also contributes to environmental sustainability, aligning with global building standards.Despite higher perceived initial costs and limited local expertise, the long-term economic and sustainability benefits are significant. With supportive policies, training, and awareness, steel frame prefab construction can transform warehouse

development in Nigeria. Overall, embracing this technology ensures cost-effective, durable, and environmentally responsible building solutions.

RECOMMENDATIONS

1. The government of Nigeria should introduce supportive policies, tax incentives, and regulatory frameworks that encourage the adoption of steel frame prefabricated systems in industrial and warehouse construction.
2. Professional bodies and construction institutions should provide technical training for architects, engineers, and builders on steel frame design, prefabrication processes, and sustainable detailing techniques.
3. The use of Building Information Modeling (BIM) and other digital construction tools should be promoted to enhance precision, coordination, and lifecycle performance of steel frame warehouse projects.

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