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Assessment of Building Collapse in Nigeria: The Major Causes and Practical Remedies

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Abstract
Over the past years, the magnitude of the occurrences of building collapse has led to the loss of life and properties in Nigeria. Research shows that in recent times, the collapse of building in Nigeria is becoming increasingly rampant and if stringent measures are not engaged to curb this menace, there could be cases of more devastating challenges in future. In a bid to and provide practical measures through which the menace of building collapse can be curbed, this study examines the causes of building collapse in Nigeria. The methodology includes; conduction of investigations and site inspections and secondary data. The study reveals that building collapse in Nigeria emanates majorly from; overloading, lack of maintenance, illegal Alteration or conversion of existing buildings, quackery, use of inadequate/improper foundation, inadequate preliminary site investigation, poor concrete mix ratio, inadequate structural analysis / design, lack of adherence to material specification / poor building material specification, inadequate supervision by professionals. Force majeure was also identified one of the causes of building collapse. Moreover, based on the results obtained in this study, recommendations were made to prevent the future occurrence of this menace. It is concluded in this paper that building collapse in Nigeria could be substantially reduced if the identified pitfalls are avoided.
Keywords: Building Collapse, Building Construction, Structural Failure, Nigerian Construction

1. Introduction
Building collapse is a menace that not only plagues Nigeria but other developing countries as well. However, Nigeria has suffered its share of building collapse in the past with several cases of buildings collapsing and killing scores of people. Many lives and properties have been lost in the collapse of buildings in Nigeria. According to Bertram (2018), the southwest zone of Nigeria has the highest record of building collapses in the last eight years, with Lagos accounting for about 134 deaths and 159 injuries. He added that the figure was without reference for the tragic incident at the Synagogue Church of All Nations (SCOAN), which took place on September 12, 2014. It was an incidence of a collapse of a six-storey SCOAN guest house that led to about 115 deaths and 131 injured. On December 10, 2016, Nigeria was hit by a tragedy when a church collapsed in Uyo, the capital of Akwa Ibom; killing over 200 people. On September 22, 2015, a building collapsed in the Lekki axis of Lagos State. In May 2016, a four-storey shopping complex collapsed in Ogun State, which left many dead. In October 2015, a three-storey building collapsed in Lagos. (Samod, 2017). Sadly, there has been an increase in the rate of building collapse in Nigeria in recent years. Despite the absence of highly destructive natural disasters in Nigeria, the hazard of building collapse continually leaves an indelible mark on the country's timeline. Further documentation of occurrences of building collapse in Nigeria is contained in this study.

2. Methodology
This study will be based on the personal experiences of the author and secondary data from national newspapers, books, reports, the internet and past works related to building collapse in Nigeria.

3. Factors Responsible For Building Collapse In Nigeria
The causes of building collapse as due to man's negligence in some vital areas in construction such as soil investigation, incorporating design for extra loads, stress from winds, earthquakes, uneven terrain, use of substandard building materials, poor monitoring and overall poor workmanship Oloyede, Omogun and Akinjare (2010). Collapse is a state of complete failure, when the structure has literally gives way and most members have caved-in, crumbled or buckled; the building can no longer stand as originally built thereby leading to the inability of the structure to perform its intended functions. Madu, (2005), identified causes of building failure as due to natural occurrences such as earthquakes, tornadoes, flood, et cetera. These and other factors responsible for building collapse are discussed as follows.

3.1 Overloading
Overloading in structures occurs when the dead load and life load on the structure exceeds the projected estimation of load the structure was designed and constructed to carry. Many building collapses has resulted from cases where the foundation a of structure was designed to carry a two-storey building and overtime, the client decides to fallaciously add more floors to the building. Chendo, (2015) posits that Imposing additional floors beyond original design provision is a common practice in Nigeria. Event centers and opera theatres are

also subject to overloading if not properly designed. Overloading has led to collapse of several buildings in Lagos. One of such incidence was the Meiran building collapse in 23rd July, 2017 that claimed the lives of two people.

3.2 Lack of Maintenance

as the saying goes, "a stich in time saves nine". Likewise, buildings need active periodical maintenance works as buildings and physical developments deteriorates as a result of several factors overtime. Thereby, making it impossible for them to fully perform the functions as initially designed. The effects of climatic conditions, environmental hazards such as; fires, floods and earthquakes et al and facility use may require works to be done in order to improve, restore or expand and put facility to the level of acceptable standards. Many structures have weakened over time because of lack of maintenance and repair works as at the time when needed thereby making the building susceptible to collapse. Amadi, Eze, Igwe, Okunlola and Okoye (2012) posits that adequate maintenance of building is necessary for the safety and durability of the structure and poor management and maintenance in buildings leads to development of cracks on the walls, differential settlement and premature ageing of the structure

3.3 Illegal Alteration or Conversion of Existing Buildings

To carry out building conversion schemes or expansions, remodeling or renovations on an existing building, the structural members and their locations within the building must be identified and avoided in the demolition exercise to avoid jeopardizing the structural integrity of the building. This is to be done by a by a structural engineer. For example, in the case of a conversion of a residential building to an industrial building; refurbishment, renovations, extension and expansion schemes may be put in place to match the new use of space. These schemes might require that some buildings components like the walls be demolished, therefore it is important to carry out a structural analysis of the building to identity the main structural members of the building. Failure to do this could lead to the costly errors of demolishing structural members which would jeopardize the structural integrity of the building and thereby lead to a collapse of the building. A Structural Engineer is in the best position to certify the structural integrity of a structure, especially when it comes to changing its use.

3.4 Quackery

A quack is a fraudulent person who pretends professionally or publicly to have skill, knowledge, or qualifications he or she does not possess. Such people have no recognition buy any of the existing professional bodies of their professed profession. Quackery can be therefore referred to as the promotion of fraudulent or ignorant practices. Amadi et al. (2012) state that the professionals in the building industry in most cases do not have their services sought for due to one reason or the other and that It has been observed that due to high cost of consultancy fees needed to engage the services of these professionals, most Nigerians prefer to cut cost by engaging the services of non-professionals (quacks) who lack the needed experience in construction sector. Clients who in a bid to cut cost employ quacks and thereby puts the structural and functional integrity of the building in danger and thereby put the lives of the prospective building users in jeopardy. Jobs done by quacks either at the design stage, construction stage and post construction stage are usually substandard as their lack the technicality to achieve design and construction goals, therefore to avoid building collapse, Registered and qualified professionals should be commissioned to execute the project.

3.5 Use of Inadequate / Improper Foundation

A foundation is that part of a building which is in direct contact with the ground with the primary aim of transmitting and spreading the loads (dead and live load) of the building over a sufficient area of soil underneath to increase lateral stability of the structure thereby avoiding undue settlement. Lambe and Whitman (1979) defined foundation as the part of the structure in direct contact with the ground and which transmits the load of the structure to the ground which plays an important role in the construction of building structures. He added that It is expected to carry all the dead, super-imposed and wind loads from a building to the soil on which the building rests in such a way that settlement of the structure is limited, so that failure of the underlying soil is prevented. Amadi et al. (2012) revealed that most of the foundations in Nigeria are designed without considering the soil type on which they rest upon. Adding that it is vital that adequate soil investigation should be carried out before designing of foundation in-order to have a suitable design to suit the local geology of the area. There are mainly four types of foundation being used, which are; pile foundation, strip foundation, raft foundation and pad foundation. These foundation types vary in their support mechanisms and load distribution system they provide. In peculiar cases, two foundation types may be combined to achieve a desired result. There are a number of factors that determines the type of foundation suitable for the proposed structure. They include; (i) soil type (ii) site condition (iii) load bearing capacity of the soil (iv) evaluated weight and load of the proposed superstructure (v) economic and other constructional considerations. An improper consideration of any of these factors could

make the foundation unfit for the proposed superstructure and consequently lead to the collapse of the building.

3.6 Inadequate Preliminary Site Investigation

Preliminary site investigation works are operations carried out to determine the suitedness of the site for the purpose of use and more importantly, for the proposed structure. It includes the investigation of; site topography, soil strata, load-bearing capacity of the soil on site, propensity of the site to flooding and information about previously existing structures or features on site et cetera. In cases where this investigation is executed carelessly, there is a high likelihood of building collapse. The resilience of a building against collapse is not only dependent on the soundness of its structural elements but also upon the ground that bears it. Adequate site investigation prevents the issue of foundation problem because it would ensure that the most appropriate foundation is prescribed. Seeley (1987) said that all potential building sites would need to be investigated to determine their suitability for buildings and the nature and extent of the preliminary work that would be needed. Particular attention should be given to the nature of the soil and its probable load-bearing capacities, as there may be variations over the site. The past history of the site should be investigated with particular reference to the former existence of trees, water level, borehole log, underneath soil strata and waste dumps.

3.7 Poor Concrete Mix Ratio

Concrete is formed from a mixture of cement, sand, gravel and water in their balanced proportion that hardens to a strong stony mass over a varying length of time. Concrete mix ratios differ depending on what is to be constructed and the mode of the construction. Masonry workers sometimes misunderstand the mixing ratios of the concrete, many constructions are done with the use of wheelbarrows or other sizeable containers by workers as measuring gauges instead of using actual measuring gauges to measure cement. Furthermore, in Nigeria, concrete is being widely used as a construction material. Therefore, the need to achieve a functional concrete cast is of utmost importance. To achieve this, the cement, sand and stone must all be sound and have the types and qualities specified. The result of poor concrete works is building collapse. Concrete exhibits high strength in compression but it also exhibits weakness in tension. Therefore, Steel is embedded within the concrete to reinforce it thereby making up for its weakness in tension. Reinforced concrete therefore caters for both compressive and tensile stresses adequately. Steel reinforcement rods of suitable diameter and number must be positioned in within the mold or formwork before the concrete is cast to achieve this.

3.8 Inadequate Structural Analysis / Design

Adequate evaluation of the load a structure would support is tantamount to be generation of a wholistic structural design. The structural design should factor in all possible loads the building would be subjected to and the building should be strong enough to carry the load and transmit it evenly to the supporting ground. When the load a building is subjected to is heavier than what it was designed to carry, the building is set to fail structurally. In addition, at all points of the construction, the structural stability of the building must be tested. A holistic building design not only includes the Architectural design; it also includes structural, mechanical and electrical and engineering designs. A building without an accurate structural design would not stand the test of time, it would eventually collapse. The availability of Building Information Modelling (BIM) software's now present us with the ability to not only draft and design but also to analyze the building structurally and simulate the building. This helps to evaluate and predetermine the building's performance under several loading conditions. It also helps to evaluate the reception to natural ventilation, natural lighting, energy usage, response to change in weather et cetera.

3.9 Lack of adherence to Material Specification / Poor Building Material Specification

Each construction projects usually has design and material specifications, all that is contained in the construction design documents must be implemented and strictly adhered to by the construction team (contractors). The quality and quantity of specified building material must also be adequate to meet the demands of the building design; good building constructions are enhanced by materials of good quality. For example, In 2016, an event centre under construction in Oda-road, Akure collapsed. It exterior walls literarily gave way some days after the steel roof trusses where installed. It was later discovered that the contractor failed to use the specified thickness and number of steel rods in columns embedded along the walls. As a result of that, the columns and walls could not carry the loads of the roof trusses. The uses of poor building material specifications have been possible root causes of collapse in Nigeria. In building construction, the materials that are essentially used on construction sites are cement, sand, gravel, granite chipping, timber, iron rods and sandcrete blocks. Materials specifications must fulfil the intended construction purpose and must be of adequate standard to prevent building collapse.

3.10 Inadequate Supervision by Professionals

Efficiency and accuracy in construction depends largely on effective supervision of works. Sometimes, even

when the professionals have done a proper job, masonry workers could misinterpret the information during construction. It is therefore imperative for the construction to be supervised by a professional primarily to ensure that employer's requirements as expressed in the contract documents are correctly executed on site. Chendo (2015) have found that sometimes firms resort to use unqualified staff to act as principals on construction sites in order to save cost. He further added that the consequence of this practice is that the unqualified staff may not be competent enough to detect fraudulent practices of smart contractors. Professional supervision allows for smooth synergy between all involved in the construction process and it involves the intricate knowledge of workmanship and materials. The building professionals must also ensure that they give room for the input of other professionals when it they need to do so. Onyemachi and Uji (2005) found that architects sometimes contribute to building collapse by not involving engineers at all stages of construction. Amadi et al. (2012) posits that currently in Nigeria, it is not uncommon to find architects undertaking the entire construction of building projects alone without the consultation of engineers.

3.11 Natural Disaster & Climate

Although human negligence has been the major cause of building collapse in Nigeria. However, natural disasters also referred to as force majeure natural disasters such as floods, heavy windy, heavy rains, et al have also been recorded as causes of building collapse. Many of our buildings have failed due to persistent incidence of weather. A good building is not that which merely fulfils the purpose for which it is designed and erected, but a building comely and able to withstand the onslaught of weather conditions (Ogunsemi,2002).

Table 1: List of selected Building Collapse in Nigeria between 1999-2018

S/No	Property Description	Location	Status	Date of Collapse	Possible Cause	Casualty
1	Three-Storey residential building	Lagos state	In use	1999	Carelessness, substandard materials	4 deaths
2	Three-Storey building	Lagos state	In use	1999	Structural failure	None
3	Three-Storey residential building	Lagos state	In use	1999	Structural failure, Rainstorm	35 deaths
4	Two-Storey residential building	Ogun state	In use	1999	Rainstorm	20 deaths
5	A Storey residential building	Lagos state	In use	1999	Rainstorm	N/A
6	Residential Storey building	Lagos state	In use	2000	Faulty design, carelessness	N/A
7	Three-Storey residential building	Lagos state	In use	2000	Incompetence, structural failure,	5 deaths
8	St. Dennis Catholic Church building	Lagos state	In use	2000	Structural failure	3 deaths
9	State High School building	Lagos state	In use	2000	Crowd pressure, overloading	1 death, 2 injured
10	Two-Storey Building	Lagos state	In use	2000	Deteriorated slab	2 deaths
11	Building at Isako	Lagos state	In use	2000	Structural failure	5 deaths
12	Two-Storey Mosque building	Lagos state	In use	2001	Unauthorized conversion	7 deaths
13	A Storey residential building	Osun state	Under construction	2001	Structural failure	7 deaths
14	Two-Storey residential building	Lagos state	In use	2004	Dilapidated structure	N/A
15	Building on Three floors	Lagos state	In use	2004	Not disclosed	N/A
16	Building on Two floors	Lagos state	In use	2004	Not disclosed	N/A
17	Commercial building on Two floors	Lagos state	In use	2005	Not disclosed	N/A
18	Three-floor commercial building	Lagos state	In use	2005	Not disclosed	1 death
19	Commercial building on Four floors	Lagos state	In use	2005	Not disclosed	1 death
20	Four-floor residential / Commercial building	Lagos state	In use	2006	Ignorance, greedy landlord	7 deaths
21	21-Storey Bank of Industry building	Lagos state	In use	2006	Aftermath of fire, heavy wind and rain	2 deaths, 23 injured
22	Four-Storey block of 36 flats (The Titanic Building)	Lagos state	In use	2006	Faulty construction	28 deaths
23	Multi-Storey building	Kano state	In use	2007	Faulty design, structural failure	Several people
24	Building used as primary school	Oyo state	In use	2007	Use of substandard material, poor workmanship	13 deaths
25	Five-Storey shopping complex	FCT	Under construction	2008	Structural failure, bad workmanship	2 injured, 100 trapped
26	Two-Storey residential Building	Ogun state	Under construction	2008	Violates planning approval,	2 deaths
27	Six-Storey teaching complex	Oyo state	Under construction	2008	Use of substandard material, poor workmanship	5 deaths
28	Uncompleted building	Ogun state	Un-completed	2009	Substandard material, hasty construction	3 deaths, 11 injured
29	Building under construction	Lagos state	Under construction	2010	Use of Substandard material	4 deaths, 12 injured
30	Uncompleted 3-Storey Building	FCT	Un-completed	2010	Undisclosed	5 deaths, 40 trapped
31	Four-storey Building	Lagos state	In use	2010	Structural defects / overloading	3 deaths

32	Two-Storey Zenith Bank Building	FCT	In use	2011	N/A	N/A
33	Four-Storey Hospital Building	FCT	Not ascertained	2011	N/A	N/A
34	Five-Storey Hotel building	Lagos state	In use	2011	N/A	N/A
35	Three-Storey Block of Flats	Enugu state	In use	2012	Structural defects	N/A
36	One-Storey residential building	Anambra state	Un-completed	2012	Defective material	N/A
37	Two-Storey School building	Plateau state	In use	2013	Structural failure	10 deaths
38	Three-Storey building	Lagos state	In use	2013	Dilapidated structure	7 deaths
39	Six-Storey Guest house building	Lagos state	In use	2014	Structural failure	115 deaths, 131 injured
40	Three-Storey building	Lagos state	In use	2015	Weak structure	Nil
41	Residential Building	Lagos state	In use	2015	Gas explosion	3 injured
42	Five-Storey building	Lagos state	Under construction	2016	Violation of approved number of floors	32 deaths
43	Four-Storey shopping Plaza	Ogun State	Under construction	2016	Under investigation	1 death
44	Three -Storey building	Rivers state	Uncompleted	2017	Structural failure	Nill
45	A Storey building	Lagos state	In use	2018	Deteriorated structural framework	2 deaths

Source: Olayinka et al (2017); Author's Secondary Data (2018)

4. Recommendations

The following measures are recommendations to guide against future occurrences of building collapse in Nigeria.

4.1 Accurate Preliminary Study

A comprehensive and accurate soil investigation is the first step to insure a building against collapse. Geotechnical experts should be consulted to carry out a soil test particularly on reclaimed lands and other soils with peculiarities. The results of the soil test from the geotechnical expert would serve as a basis for generating a suitable structural design. The soil type and load to be carried would determine the intensity of soil investigations that would be carried out.

4.2 Accurate Structural Evaluation

Accurate structural evaluation must be done to guarantee the resistant of the building against applied load, environmental forces and collapse. Building Information Modelling (BIM) software's should be used to analyze the building structurally and simulate the building's performance under several loading conditions before the construction of the building begins. Loading test should also be carried out at pivotal stages in the construction of the building. Furthermore, Proper structural evaluation and analysis must proceed building change of use as the factor of safety embedded in the design to suit the initial purpose of the design may not be strong enough to withstand the demands of the newly proposed building use. Also, it would help to create a safer demolition plan in case of remodeling, extension, expansion and servicing.

4.3 Use of Specified Building Materials and Construction Methods

Contractors and everyone involved in the building project must ensure that there is strict adherence to the method of construction that is stipulated in the project documents. Quality and quantity checks should be carried out on all building construction materials before commencement of any construction. The quality control to achieve the desired result is very important. Therefore, Standard organization of Nigeria, (SON) should monitor the standard of blocks moulded in block industries and impose minimum standard in terms of sand-cement ratios.

4.4 Routine Structured Maintenance and Integrity Test

In course of the lifecycle of a building, a structured routine maintenance check must be carried out on the building to correct defects. This is to ensure that the building remains structurally sounds and it in no way possess a treat to the building users. Usually, before a building fails completely, it must have been giving off warning signs. However, when these signs are ignored, the defects pile up and lay compromise to the structural integrity of the building. It is the disregarding of these signs that leads to the eventual collapse of the building. Therefore, early warning signs should be resolved with urgency to avoid the collapse of the building.

4.5 Education

Training and skill enhancement workshops should be organized to provide training, for artisans and craftsmen in the building industry. Continuous professional development should be encouraged by both the professional bodies and the government on modern trends in the building industry. To keep members of the building industry up to date on better construction practices.

4.6 Engagement of Competent Professional

The employment of the qualified personnel is key to the success of any construction project. Government and other concerned agencies should screen those getting involved in housing projects. This is in addition to the suggestion of Chendo et al. (2015) Professionals in the building industry should maintain their integrity and professional ethics and work in accordance to standard practice procedures laid down by the standard form of building contracts especially when they play in the hands of ignorant clients. Construction work should only be carried out by registered and competent professionals rather than engaging unskilled contractors. According to Walter (2015), since It is generally said that the best way to manage a crisis is to avoid it, it is advisable that the best way to manage crisis resulting from building collapse is to prevent it by avoiding the use of quacks and non-building professionals in any major building projects.

4.7 Discouragement of unapproved constructions

All clients or building developers should be compelled to comply with approved building regulations before the construction and demolition of their buildings and that all building construction works should be well designed and supervised by a registered member of Architects' Registration Council of Nigeria (ARCON), Council for the Regulation of Engineering in Nigeria (COREN) and Council of Registered Builders of Nigeria (CORBON).

4.8 Government Regulations

The Government at all levels should be adequately staffed and equipped with professionals to perform regular evaluation of defective and such structures deemed unsafe for habitation should be demolition should be demolished before it collapses and causes havoc on lives and properties. Government should also intensify public enlightenment, placing emphasis on how building disasters could be prevented rather than managing situations which might be costlier.

5. Conclusion

Building failures and collapse has always led to a painful loss of life and properties. This study reveals however that many if these causes can be prevented by engaging appropriate measures. However, clients, professionals and the government have their roles to play to achieve this goal. Clients in a bid to cut cost sometimes cut-corners thereby puts the structural integrity of the building in danger and by extension, putting the lives of the prospective building users in jeopardy. Professionals and everyone involved in the building project must ensure that there is strict adherence to the required standards, specifications and method of construction without compromise. The Government at all levels should also intensify public enlightenment, placing emphasis on how building disasters could be prevented rather than managing situations which might be costlier. The government should also see to it that building laws and codes are strictly adhered to before and during construction and throughout the lifecycle of the building. This would compel everyone involved in building and construction processes to do their jobs correctly.

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