NIPES

Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng

The Integrity of Engineered Structures: The Relevance of Earthquake Engineering Considerations in Nigeria

[1] R. I. Umasabor and [2] O.E.Alutu
Civil Engineering Department, University of Benin
[1]Email: princerich247@yahoo.co.uk,umasaborrichie@uniben.edu, Phone no: 08062486118
[2] Email: alutuoe@yahoo.com, Phone no: 07061079418

Article Info

Received 15 July 2021
Revised 28 July 2021
Accepted 5 August 2021
Available online 31 August 2021

***Keywords**: Failure, Structural integrity, Earthquake, Lateral forces, Seismic code*

https://doi.org/10.37933/nipes.e/3.3.2021.5
https://nipesjournals.org.ng

Abstract

The purpose of this paper is to create awareness in the structural engineering profession in Nigeria that earthquake lateral forces should be considered in the designs of structures in seismic active zone s in the country to mitigate its effects on the structural integrity of structure. Literature reviews were carried out to investigate the possibility of earthquake occurrence in Nigeria and results showed that earthquakes of magnitude 3.5 to 4.5 on the Richter scale have occurred in some places in this country in recent times. More so due to the discovery of a NNE-SSW trending Ifewara-Zungeru fault zone which has been shown to be linked with the Atlantic fracture system close to Nigeria, will make it more prone to earthquake threats. Although, several earthquakes may be mild at present, but these earth tremors may portends a built up to major earthquakes in future. Therefore, structural engineers should be prepared for the future by yielding to the clarion call to include earthquake lateral forces in designing for structures in seismic active areas in Nigeria to mitigate its effects on the structural integrity of structures.

1. Introduction

Buildings and related structures that experience severe damages, performance problems, out-right collapse or related forms of failure are not as rare as many engineers might imagine or care to admit [1]. The truth is that a wide variety of tragic structural failures occur daily throughout the world. The destruction of the World Trade Centre (WTC) on September 11, 2001 was not only the largest mass murder in US history but a big surprise for the Structural Engineering profession, the biggest since the collapse of the Tacoma Bridge in 1940 [2].
Ever since structural failures make news throughout the world, their investigations are becoming an active field professional practice [3]. These areas of study include engineering investigation and determination of causes of failures of building in service or under construction and other related constructed facilities. Structural failure has been likened to pathology where a specialized group of doctors study diseased tissues for the purposes of extracting information for the benefit of the profession. The word pathology was used by Akeju [4] to describe investigations necessary to discover and remove the causes of failure in a structure. Hutton [5] used "pathology of buildings" to describe failure studies in buildings and called on anybody (worldwide) interested in forming a "society of building pathologist" to join hands with him for the sole aim of assemblage of data for failure structures. Moreso, Parffit and Parffit [1] called for failure education in the classrooms and

noted that the key to better engineering design and construction is the knowledge gained from failure studies.

Failure is anything from simple loss of serviceability to outright collapse which could be during construction or during the time the structure is in service. Majority of failures falls into loss of serviceability in which the engineer is called upon to repair, maintain, refurbish, renovate or reinstate the structure while in the case of outright collapse; he may be required to begin again. In the former case, it would require trouble-shooting to assess the residual strength of the structure after being subjected to excessive loading or deterioration due to use or in the case of structure under construction, failure may be due to use of sub-standard materials, use of excess water in concrete during mixing of concrete to avoid the difficulty arising from the need for proper vibration of the concrete during concrete cast.

A number of buildings, bridges, GSM masts, etc, have collapsed in recent in Nigeria. Reasons given ranges from lack of maintenance, use of sub-standard materials for construction, lack of adequate supervision, lack of adequate design and to no design at all. Unfortunately, investigations are carried out only when failures are catastrophic or lives are lost or when a dissatisfied client goes to court or when a commission of inquiry is instituted.

Furthermore, failure studies are few and partial in their coverage of breadth and depth of failures concerned. In short most failures are ad-hoc projects as they are not continued thereafter. When an integrity assessment is carried out on a structure, it refers to the safety and reliability of the structure and the aim is to prevent catastrophic failure and ensure continuous profitable operation of the structure throughout its designed life. Integrity test on existing building either completed or still under construction are commissioned in Nigeria today, only when doubts are cast as to whether concrete used in the construction or cast over a certain period of time had an appropriate strength of say 20N/mm^2. The apparatus used for integrity test in recent time may be the Rebound Hammer, Ultra Pulse Velocity and others. Examples of integrity test results carried out using the rebound hammer on columns cast in a building with doubtful integrity and on ground floor concrete slab properly cast are shown in Figure 1 and Figure 2.

In Figure 1, all compressive strength values that are above the line of allowable concrete strength passed the integrity test, while those below it failed the test. In Figure 2, all the measured compressive strengths passed the integrity test since all the measured compressive strengths were above the line of allowable compressive strength.

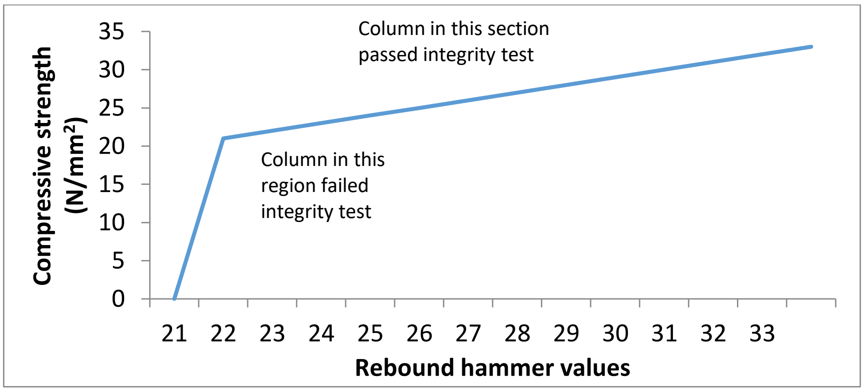


Figure 1: Graph of compressive strength against rebound value for partly failed columns

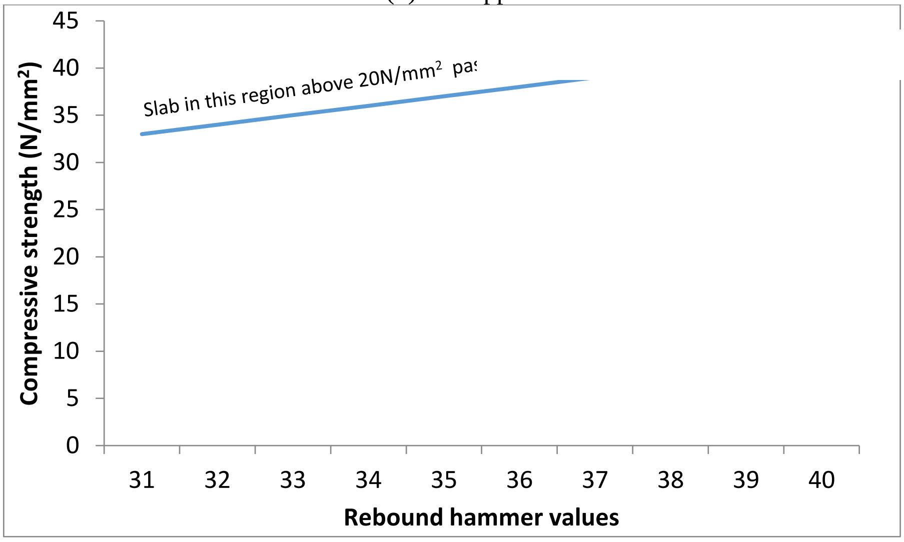


Figure 2: Graph of compressive strength against rebound value for ground floor concrete slab

1.1. Earthquake and Its Effect on Structures

When an earthquake of magnitude 8.8 on the Richter scale occurred off the coast of Chile on February 27, 2010, it affected 80 percent of Chile's population. Damage to lifelines was caused by strong ground shaking, permanent ground deformation, lateral spread, and a tsunami in the coastal areas of Biobio and Maule. Lifeline services were significantly disrupted for the first week, at a considerable cost to Chile's economy [6]. These ground motion resulting from earthquakes presents unique challenges to the design of structures. Earthquakes produce large magnitude forces of short duration that must be resisted by a structure without causing collapse and preferably without significant damage to the structural elements. The lateral forces due to earthquakes have a major impact on structural integrity. Lessons from past earthquakes and research have provided technical solutions that will minimize loss of life and property damage associated with earthquakes. Special detailing is required, and for materials without inherent ductility, such as concrete and masonry, a critical part of the solution is to incorporate reinforcement in the design and construction to assure a ductile response to lateral forces [7].

1.2. Earthquake Design Codes

Building codes establish minimum requirements for building design and construction with a primary goal of assuring public safety and a secondary goal, much less important than the primary one, of minimizing property damage and maintaining function during and following an earthquake. With respect to earthquake hazards, developments of code criteria depend on the levels of seismic risk and the establishment of appropriate design requirements commensurate with those levels of risk. Since the risk of severe seismic ground motion varies from place to place, it logically follows that seismic code provisions will vary depending on location. In the United States, the building codes used was the Uniform Building Code (UBC), the Standard Building Code (SBC), and the National Building Code (BOCA).

Given the greater frequency and intensity of earthquakes in the west, it is not surprising that the Uniform Building Code (UBC) has traditionally placed more emphasis on seismic design provisions than the Standard Building Code (SBC) or the BOCA National Building Code (BOCA/NBC). However, this situation is changing. Representatives from the three model code sponsoring organizations agreed to form the International Code Council (ICC) in late 1994, and, in April 2000, the ICC published the first edition of the International Building Code (IBC) [7]. It is intended that IBC will eventually replace the previous three model codes. The IBC includes significant changes in seismic design requirements from the three existing model building codes, particularly in how the level of detailing requirements for a specific structure is determined. The existing international seismic design codes used around the world are compared in Table 1.

Table 1: Comparison of Seismic Design Codes used around the World

UBC 1991	**Eurocode 8: 1993**	**NZS 4203:1992**	**CUBIC 1985**	**NBC 2006**	**IBC 2000**
Used most in the United States of America	Mostly used in the UK	Applied in New Zealand	Used in the Carribeans	Mostly used in Nigeria	Internationally accepted seismic code
Ground motion design methods used includes static lateral forces, response spectrum or time history analysis	The ground motion design approaches used are static lateral forces, response spectrum, probabilistic, time history and capacity design.	This code uses the serviceability and the ultimate levels of design. The use of static lateral force design is limited to structures below 15 meters high, with first mode period less than 0.45 seconds or for regular building with a first mode period less than 2 seconds.	CUBIC follows the pre-SEAOC/UBC approach using k (multiplier) factors in place of R_w (divisor). Ground motion design approaches include static lateral force, time history and response spectrum analysis.	NBC follows the pre-SEAOC/UBC approach using k (multiplier) factors in place of R_w (divisor). Ground motion design approach is limited to static lateral force only and is limited to regular structures which are defined in the code	The IBC includes significant changes in seismic design requirements from the existing model building codes, particularly in how the level of detailing requirements for a specific structure is determined.

2. The Relevance of Earthquake Engineering in Nigeria

Building collapse and structural failures are everyday occurrences in the world today. It has been the concern of numerous authors [8]; [9]; [10]; [11]; [12] and [13] to search for the causes of this monster, in order to proffer adequate solution of prevention, mitigation or preparedness. However, most of these structural failures experienced in Nigeria are manmade. One wonders what happens when natural disasters like earthquakes, landslides, floods, hurricane which could be a major cause of structural failure in Nigerian due to the effects of climatic changes are considered alongside the man-made situation.

However, Nigeria lies on the eastern flank of the Atlantic Ocean, which is generally known to be quiet unlike the Pacific Ocean margins which are characterized by tectonics and occurrence of devastating earthquakes [14]. Nigerian scientists at the National Space Research and Development Agency (NARSDA) warned that Nigeria should be prepared for earthquake experience because tremor is a sign that Nigeria is not immune from earthquake occurrence.

Osagie [15] gave very descriptive and well detailed information of various earth tremors that have occurred in Nigeria from 1923 to 1990. The earth tremors included Warri town in 1923, Ohafia in 1933, Yola in 1984, Jere town of Kaduna state in 1990, Osererun hills in Gombe council area of Gombe state and Amauze Ede-Obela in Edema council area of Anambra state both in 1988. Also, an earth tremor occurred in Abeokuta in 1986 and Ibadan in 1990. Osagie [15] queried the age long belief that Nigeria was a seismic safe haven due to the series of earth tremors experienced in the country. He warned that these incidences of earth tremors could be a build-up to a major earthquake in future.

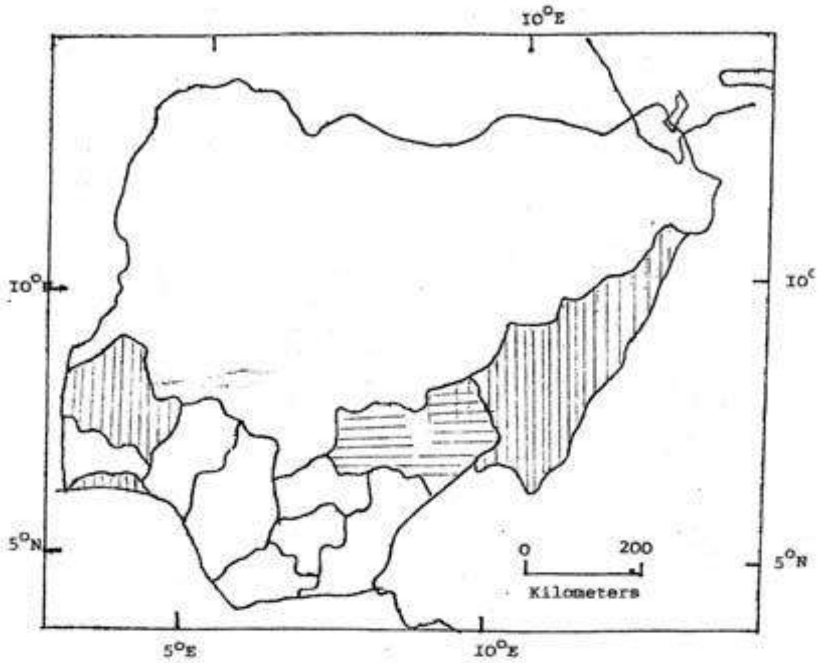
Furthermore, Osagie [15] identified seismically active zones in the country which are; the south-west zone stretching from Ijebu areas to Ibadan areas, the Cross Rivers Basin, the Gombe Trough and the Benue Valley (Figure 3). With the identification of the potential distinct earthquake belts in Nigeria, therefore engineering structures that would be constructed in those areas need to be designed against earthquake forces in order to mitigate its effect, on the structural integrity.

Moreover, Akpan and Yakubu [14] also indicated that although Nigeria is not located within the major seismic zones of the world; several minor earthquakes have been experienced in some parts of the country, over the years. He also reported that the first widely reported occurrence of an Earth tremor in Nigeria was in 1933. Other events were reported in 1939, 1964, 1984, 1990, 1994, 1997, 2000 and 2006. The intensities of these events ranged from III to VI based on the Modified Mercalli Intensity Scale. Out of all these events, only the 1984, 1990, 1994 and 2000 events were instrumentally recorded. They had body wave magnitudes ranging from 4.3 to 4.5 on the Richter scale, local magnitudes between 3.7 and 4.2 on the Richter scale, and surface wave magnitudes of 3.7 to 3.9 on the Richter scale. When these events occurred, there were no functional seismological observatories in Nigeria.

However, that has now changed with the establishment of a seismographic network managed by the Centre for Geodesy and Geodynamics (CGG), Toro, Nigeria in 2002. Presently, the network has six (6) operational stations equipped with 24-bit 4-channel recorders and broadband 30-second seismometers in Nsukka, Awka, Abakaliki, Ife, Kaduna, and Minna [16]. Efforts are being made to establish more stations and migrate to real-time collection of seismic data using the general packet radio service (GPRS) technology as well as automatic location of events. Remote sensing, geological and geophysical studies have revealed the presence of a NNE-SSW trending Ifewara-Zungeru fault zone which has been shown to be linked with the Atlantic fracture system which is close to Nigeria. The dynamics of the Atlantic fracture zones have been suggested to be responsible for the seismic activities experienced in the areas. Environmental disaster of varying origin from man-made to natural is one of the most negative effects of the built environment on man. An assessment of the magnitude of these disasters and an evaluation of the existing capacities to prevent, mitigate or prepare for them are necessary tools to provide future safe living for man in his built environment [17].

2.1. Justification for Recommending Earthquake Consideration in Nigeria

Although we have experienced some earthquake tremor of magnitude 3.5 to 4.5 on the Richter scale in Nigeria, which may be termed mild, but the continuous earth tremors in some areas in the country is a pointer to major earthquakes in the future and warnings from Nigerian scientists at the National Space Research and Development Agency (NARSDA) should not be ignored because earth tremor is a sign that Nigeria is not immune from major earthquake occurrence.



Source: Osagie, [15]

Figure 3: Map of Nigeria. (Areas with Seismic Activity are Shaded).

Adepelumi [18] studied the Engineering Implications of Earthquake Monitoring and Modeling using Nigerian as case study. He used an empirical earthquake recurrence model for a time period of 2008-2029 considering Ijebu-ode as a study area. He discovered that the probability of earthquake occurrence in the study area between 2009 and 2028 increase from 2.8% to 91.1%. The results showed that the probability of two earthquake events of magnitude 5 and above on the richter's scale happening within the predicted years, specifically before 2028 is high.

More so when remote sensing, geological and geophysical studies have revealed the presence of a NNE-SSW trending Ifewara-Zungeru fault zone which has been shown to be linked with the Atlantic fracture system, will make it more prone to earthquake threats [19]. The dynamics of the Atlantic fracture zones have been suggested to be responsible for the seismic activities experienced in the seismic areas in Nigeria. The National Building Code 2006, section 8.8.13 also made provisions for earthquake lateral forces in buildings. Therefore, structural engineers in Nigeria should ensure the inclusion of earthquake lateral forces in their designs for structures in seismic active areas in Nigeria in order to mitigate its effects on its integrity.

3. Conclusion

The possibility of earthquake occurrence in Nigeria have been proven and buttressed with the release of the Nigerian Building Code 2006 that made provisions for seismic loading. However, the code is limited to static lateral force method only in the determination of ground motion forces and the formulae also in the code are not scientific enough when compared to other seismic code around the world. Efforts should be made to update the National Building Code 2006, to cater for more method of analysis of ground motion forces and correct the formulae related to earthquake lateral forces.

The knowledge of the seismic areas in Nigeria would assist engineers in designing for earthquake forces which have a major impact on structural integrity.

References

[1] Parffit and Parffit, (2007) " Failure Education: The Key to better Engineering Design" Structure Magazine, National Council of Structural Engineer's Association, pp.10-12

[2] Bazant, Z.P and Verdure, M. (2007) " Mechanics of Progressive Collapse: Learning from world Trade Centre and Building Demolitions" Journal of Engineering Mechanics Vol.133, No.3, pp.308-319

[3] Ratay, R.T.(2007) " Forensic Structural Engineering: Focus on the United States" Structural Engineering International, pp. 114-118

[4] Akeju, T.A.I. (1984) " Lesson from some Recent Structural Failures" The Nigerian Engineer, Vol 19, No.2

[5] Hutton, G.H. (1987) " Pathology of Building" The Structural Engineer" Vol.65, No.1 pp.13-14

[6] ASCE 7, (2000) "ASCE Minimum Design Loads for Buildings and other Structures", American Society of Civil Engineers, Washington, DC.

[7] [7] Ghosh, S.K.,(2000) " Masonry today" Seismic Design Considerations in Model Codes" PCI Journal pp.3-5

[8] Opara P. (2006) Building Collapse in Lagos State: Causes and Recommendations. Journal of Technology and Education in Nigeria Vol.11 No.1 pp. 58-65.

[9] Opara, P. N. (2007) "Building Failures and Collapses: A Case Study of Portharcourt, Nigeria" Journal of Technology and Education in Nigeria, Vol.12 No.1 pp.35-39.

[10] Oyewande, B. (1992) "The Search for Quality in the Construction Industry." Builders Magazine

[11] Chinwokwu, G. (2000) "The Role of Professionals in Averting Building Collapse" Proceedings of a 2-Day Seminar of the Nigerian Institute of Building (Lagos State Chapter) on Building Collapse, Causes, Prevention and Remedies, Lagos Airport Hotel, Ikeja 3

[12] Windapo, B. (2006) "The Threat of Building Collapse on Sustainable Development in the Built Environment" pp. 59-67.

[13] Weihen, S. (1999) "Corruption in Economic Development: Beneficial Grease, Minor Annoyance, or Major Obstacle? The World Bank Development.

[14] Akpan, O.U and Yakubu, T.A. (2010) "A Review of Earthquake Occurrence and Observations in Nigeria" Journal of Earthquake Science, Vol. 23, pp.289-294

[15] Osagie, E. D. (2008) " Seismic Activity in Nigeria" The Pacific Journal of Science and Technology Vol.9, No. 2, pp.546-551

[16] Nwankwoala, H.O. and Orji, O.M. (2018) "An Overview of Earthquakes and Tremors in Nigeria: Occurrences, Distributions and Implications for Monitoring", International Journal of Geology and Earth Sciences, Vol.4, No.4, pp.56-76

[17] Adeniran, A.J. (2013) "Environmental Disasters and Management: Case Study of Building Collapse in Nigeria", International Journal of Construction Engineering and Management, Vol. 2 No. 3, pp. 39-45.

[18] Adepelumi, A. A. (2013) "Engineering Implications of Earthquake Monitoring and Modeling: Nigerian Case Study". Conference proceedings of Nigerian Institution of Structural Engineers, Theme: Integrity of Engineering Structures and the Impact on Socio-Economic Development, pp.10-46

[19] Tsalha, M. S., Lar, U. A., Yakubu, T. A., Umar, A. K., and Duncan, D. (2015) "The Review of the Historical and Recent Seismic Activity in Nigeria. IOSR", Journal of Applied Geology and Geophysics, e-ISSN; 2321-0990, Vol.3, No. 1, pp. 48-56.