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SEISMICITY IN NIGERIA
THE NEED FOR EARTHQUAKE-RESISTANT STRUCTURES

Introduction

An earthquake is a shaking of the ground caused by the sudden breaking and movement of large sections (tectonic plates) of the earth's rocky outermost crust. The edges of the tectonic plates are marked by faults (or fractures). Most earthquakes occur along the fault lines when the plates slide past each other or collide against each other. The shifting masses send out shock waves that may be powerful enough to alter the surface of the Earth, thrusting up cliffs and opening great cracks in the ground and cause great damage such as collapse of buildings and other man-made structures, broken power and gas lines (and the consequent fire), landslides, snow avalanches, tsunamis (giant sea waves) and volcanic eruptions. A natural disaster of geological nature such as earthquakes, for instance, is a phenomenon that defies human understanding and is well known for its devastating impact on human life, economy and environment. Structures tend to respond to earthquakes in one of the following ways: bending, breaking, sinking or shaking. Buildings are complex structures made of multiple elements and components that are stressed and interact with one another when shaken by an earthquake. Buildings vary widely in size, geometry, structural system, construction material and foundation characteristics. These attributes influence how a building performs when the ground shakes.

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 [1]. This evidence of tremors observed in Nigeria has eroded the cautious optimism once held that Nigeria is aseismic or not seismogenic. While it is almost impossible to completely neutralize the damage due to earthquakes, it is possible to minimize the potential risks to humans and damage potential to structures by designing earthquake resistant structures using records of ground motion from previous earthquake occurrences and advanced technologies which make it almost possible to predict earthquake ground motion with proper understanding of seismic sources and properties of seismic waves.

1. A review of earthquakes and seismic tremors in Nigeria

Records indicate that some communities in Nigeria have experienced earthquakes in the past (Onuoha K.M., University of Nigeria, Nsukka, personal communications; [1], Fig. 1, Table 1), despite the fact that Nigeria lies far from the world's active plate boundaries. Most of the events that occurred in Nigeria were not instrumentally recorded because there was no such equipment in the country at that time. Unlike the East African region, West Africa was not known to be seismogenic in the past and because of this, most people tend to believe that seismic activities are confined to North Africa and the surrounding areas of the rift valley system in East Africa [2]. But recent findings have shown that Nigeria may not be completely free from earthquakes [1, 3]. Since tremors were recorded in Nigeria in the past, any future occurrences of Earth tremors in the country are likely going to occur along these fault zones (Fig. 2). Possible mechanisms for these intra-plate tremors have been examined to include regional stresses created by Nigeria's position between two cratons and zone of weakness resulting from magmatic intrusions and other tectonic activities in the sediments [4].

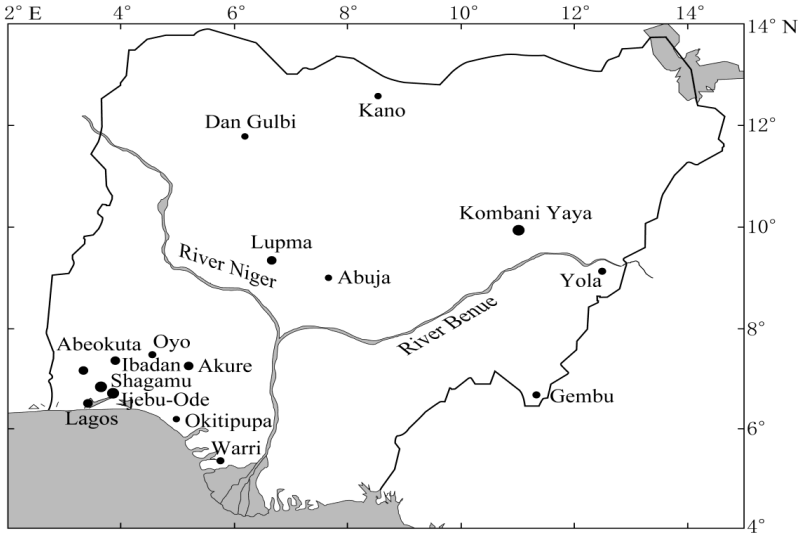

Fig. 1. Map of Nigeria showing the areas where some earth tremors were felt (diameter of the solid dot denotes intensity of the events, after [1]), not drawn to scale

Historical and recent seismicity data do indicate that disastrous earthquakes have occurred in other parts of Africa far away from the Atlas Mountain region and also in the areas far from the rift valley system [2]. This development indicates that Nigeria and indeed some West African countries are likely to witness devastating earthquakes in future. This is in line with recent review of earthquake occurrences and observations in Nigeria which shows that several minor tremors were experienced in some parts of the country in 1933, 1939, 1964, 1984, 1990, 1994, 1997,

2000 and 2006 ([1], Table 1). The intensities of these events ranged from III to VI based on the modified Mercalli Intensity Scale. Of these events, only the 1984, 1990, 1994 and 2000 events were instrumentally recorded. They had magnitudes ranging from 4.3 to 4.5 [1]. Just recently at 03:10 GMT on September 11, 2009, an earth tremor occurred in Allada, Benin Republic. This earthquake was felt in some parts of south-western Nigeria [1].

TABLE 1

Historical earthquakes that occurred and tremors that were felt in Nigeria

Year-month-day	Origin time	Felt areas	Intensity	Magnitude	Probable epicenter
1933	–	Warri	–	–	–
1939-06-22	19:19:26	Lagos, Ibadan and Ile-Ife	–	6.5(Mr), 0.3(Ms)	Akwapin fault in Ghana
1963-12-21	18:30	Ijebu-Ode	V	–	Close to Ijebu-Ode
1982-10-16	–	Jalingo and Gembu	III		Close to Cameroun volcanic line
1984-07-28	12:10	Ijebu-Ode, Ibadan, Shagamu and Abeokuta	VI	–	Close to Ijebu-Ode
1984-08-02	10:20	Ijebu-Ode, Ibadan, Shagamu and Abeokuta	V	–	Close to Ijebu-Ode
1984-12-08	–	Yola	–	–	Close to Cameroun volcanic line
1985-06-18	21:00	Kombani Yaya	IV	–	Kombani Yaya
1990-06-27	–	Ibadan	–	3.7(ML)	Close to Ijebu-Ode
1994-11-07	05:07:51	–	–	4.2(ML)	Dan Gulbi
1997	–	Okitipupa	IV	–	Close to Okitipupa
2000-03-07	15:53:54	Ibadan, Akure, Abeokuta, Ijebu-Ode and Oyo	–	4.5(mb), 0.9(Ms)	Close to Okitipupa
2000-05-07	11:00	Akure	IV	–	Close to Okitipupa
2005-03	–	Yola	III	–	–
2006-03-25	11:20	Lupma	III	–	Close to Cameroun volcanic line

2. Impact of earthquake on human life and property

Earthquakes are unpredictable and even when one is anticipated, the intensity with which it strikes is only measurable after its occurrence has left a devastating mark of huge human and infrastructural damage. Table 2 shows that recent earthquakes of the first decade of the 21st century have resulted in near humanitarian and environmental catastrophe. Over the past decade, countries across the world - both

rich and poor - have witnessed thousands of major natural disasters of which earthquakes contribute on average the highest human death toll besides material damage. It is reported that earthquakes killed the most people over the period from 2000 to 2008 - an average of 50,184 people a year.

Since disaster first struck Japan, comparisons with the January 2010 earthquake in Haiti have emerged. While the final human cost of the Japan disaster is still unknown, it is still unlikely to compare with 222,570-strong death toll from Haiti earthquake. With tropical climate and unstable land forms, coupled with high population density, poverty, illiteracy and lack of well-developed infrastructure, Nigeria, like many other developing countries, is more vulnerable to suffer from the damaging potential of such disasters. The damage to structures can depend on the material that the structure is made out of, the type of earthquake wave (motion) that is affecting the structure, and the ground on which the structure is built.

According to results from various studies [2, 3, 5] Nigeria could witness major earthquakes in the future. Adepelumi [3] employed the Empirical Earthquake Recurrence Model (a time-dependent model) to predict the probabilistic occurrences of earthquakes in the south-western town of Ijebu-Ode and environs between the year 2008 and 2028. The time interval for the occurrence of the next large earthquake in Ijebu-Ode area using the maximum of the conditional probability of earthquake occurrence was determined using the Weibull probability density model.

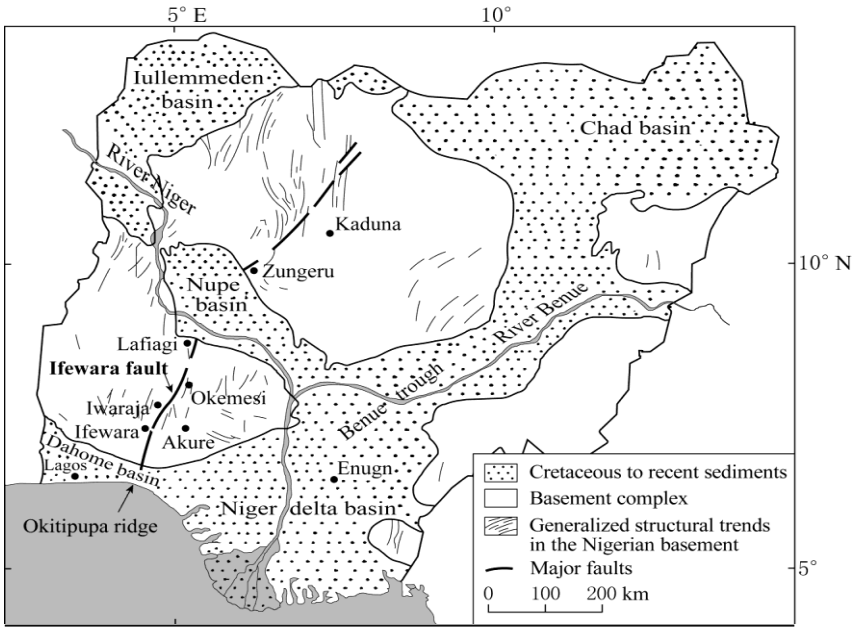

Fig. 2. Map of Nigeria showing the Zungeru-Ifewara fault [1]

TABLE 2

List of some recent natural disasters

Name	Date of event	Type of hazard	Main cities affected	Total number of deaths	Total number of affected	Total damages US$ bn
Japan earthquake	11 March 2011	Earthquake and tsunami	Sendai, Ichihara, Fukushima, Minamisanriku, Onagawa, Rikuzentaka, Ofunato, Kesennuma	5178 (as of 17.08.11)	Not yet known	Not yet known
Haiti earthquake	12 January 2010	Earthquake	Port-au-Prince	222570	3400000	n/a
Sichuan earthquake	12 May 2008	Earthquake	Beichuan, Dujiangyan, Shifang, Mianzhu, Juyuan, Chengdu, Oionglai, Deyang	87476	45976596	85
Cyclone Nargis	2 May 2008.	Tropical cyclone	Yangon	138366	2420000	4
Java earthquake	26 May 2006	Earthquake	Yogyakarta	5778	3177923	3.1
Kashmir earthquake	8 October 2005	Earthquake	Muzaffarabed	73338	5128000	5.2
Hurricane Katrina	29 August 2005.	Tropical cyclone	New Orleans	1833	500000	125
Mumbai floods	26 July 2005.	Flood	Mumbai	1200	20000055	3.3
South Asian tsunami	26 December 2004	Earthquake and tsunami	Banda Aceh, Chennai (some damages)	226408	2321700	9.2
Bam earthquake	26 December 2003	Earthquake	Bam	26796	267628	0.5
European heatwave	Summer 2003	Extreme heat	Various	72210	Not reported	Not reported
Dresden floods	11 August 2002.	Flood	Dresden	27	330108	11.6
Gujurat earthquake	26 January 2001.	Earthquake	Bhuj, Ahmedabad	20005	6321812	2.6

Source: World Disasters Report 2010, OCHA

3. Reasons for concern

The results obtained by Adepelumi [3] provide useful information regarding earthquake potential and seismicity of the study area, to the effect that most possibly, a large earthquake of magnitude $M \geq 5$ may occur in the next 30 years in Nigeria counting from 2008 or before 2038 with event occurrence tending to be very high in the next 15 to 20 years in this Ijebu-Ode seismic region. Aside the statistical prediction for earthquake occurrence in Ijebu-Ode in future, remote sensing, geological and geophysical studies had earlier revealed the presence of a NNE-SSW trending Ifewara-Zungeru fault zone (Fig. 2) which has been shown to be linked with the Atlantic fracture system [5-8]. The Ifewara area of southwestern Nigeria constitutes part of the schist belts in the Nigerian Basement Complex, a part of the African crystalline shield.

Generally, the geology of the area carries the imprint of the end-Proterozoic Pan-African orogeny [5]. Some of the other important fault systems in Nigeria are the Anka and Kalangai fault systems. Anka and Kalangai fault systems are interpreted to have resulted from transcurrent movements and particularly, the 250 km

long, NE-SW trending Ifewara fault zone has been shown to be linked with the Atlantic fracture system [5]. The dynamics of the Atlantic fracture zones have been suggested to be responsible for the seismic activities experienced in the areas [1].

Conclusion and recommendation

Researchers believe that the tremors felt over the years are a clear indication of earthquake potential and seismicity of Nigeria. Continuous experience of tremors along fault lines leads to stress accumulation and the resultant pressure could lead to surface eruption.

While it is almost impossible to curb sub-surface tectonic activities and completely neutralize the damage due to earthquakes, it is possible to minimize the potential risks to humans and damage potential to structures by designing earthquake-
-resistant structures using records of ground motion from previous earthquake occurrences which makes it possible for proper understanding of seismic sources and properties of seismic waves.

Despite the results from various studies that indicate that Nigeria could witness major earthquakes in the future, experience has shown that most structures in Nigeria are designed without recourse to seismic load and introduction into the design process parameters of ductility and energy dissipation mechanisms making them not earthquake-resistant. Buildings outside the main municipal and administrative areas are worst affected as quality control in the design and approval process is not followed before construction commences. The implication is that critical facilities in towns and cities, such as dams, rail lines, high-rise buildings, roads, could be turned into a sea of debris in event of an earthquake resulting to colossal human, material and environmental damage to the country.

Earthquakes occur without prior warning. The human, economic and environment damage it causes no doubt plunges a country backward over many years of development. Up to now we can do little to diminish direct earthquake effects. However, we can do much to reduce risks and thereby reduce disasters provided we design and build or strengthen the buildings so as to minimize the losses based on the knowledge of the earthquake performance of different building types during an earthquake. Buildings are complex structures made of multiple elements and components that are stressed and interact with one another when shaken by an earthquake. In order to ensure buildings are earthquake-resistant it is important to consider during seismic design a complex of properties and parameters that collectively and proportionately reduce the damage potential of buildings during earthquakes. These include:

1. Building material properties
   - Strength in compression, tension and shear, including dynamic effects
   - Unit weight
   - Modulus of elasticity

2. Dynamic characteristics of the building system, including periods, modes and damping
3. Load-deflection characteristics of building components.

Nigeria should learn a lesson from both developed and developing countries which have fallen victim of earthquake disasters by harnessing their experiences in the development of earthquake-resistant buildings and strengthening of existing ones. Building design must be such as to ensure that the building has adequate strength, high ductility, able to dissipate this energy and will remain as one unit, even while subjected to very large deformation.

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Abstract

Nigeria has experienced pockets of tremors of magnitudes ranging from 4.3 to 4.5, even though it is not situated where major seismic activities are observed in the world. In 2000 an earthquake with body wave magnitude of 4.4 occurred in Nigeria and was recorded by some agencies like the International Seismological Centre (ISC). Similarly, the vibrations of the September 11, 2009 event with magnitude 4.4 and epicenter at Allada, Benin Republic, almost 130 km west of Lagos, Nigeria, was felt in parts of Ibadan and Ogun State, south-western Nigeria. Most of the previous tremors occurred in south-western Nigeria where a major fault (the Ifewara-Zungeru fault), is believed to exist. It is difficult to overlook the incidence of earth tremors in the country because recurring tremors could be a build-up to a major earthquake. Despite these events, most buildings in Nigeria are designed without incorporating the effect of seismic load. This paper seeks to reiterate why it is imperative to design earthquake-resistant structures in Nigeria bearing in mind the obvious knowledge of Earth's dynamism and the country's history of the earthquake activities.

Aktywność sejsmiczna w Nigerii
Potrzeby związane z konstrukcjami odpornymi na trzęsienia ziemi

Streszczenie

Nigeria doświadczyła wstrząsów o sile od 4,3 do 4,5 mimo tego, że nie jest położona w obszarze, w którym obserwuje się aktywność sejsmiczną. W 2000 roku w Nigerii miało miejsce trzęsienie ziemi o sile 4,4 i zostało zarejestrowane przez niektóre agencje badawcze, np. Międzynarodowe Centrum Sejsmologiczne (ISC). Podobnie wstrząsy z dnia 11 września 2009 roku o sile 4,4 z epicentrum
w Allada (Republika Beninu), położonej około 130 km na zachód od Lagos (Nigeria) były odczuwalne w części Ibaan i Ogun (południowo-zachodnia Nigeria). Większość wcześniejszych wstrząsów miała miejsce w południowo-zachodniej Nigerii, gdzie występuje poważny defekt. Trudno przeoczyć występowanie wstrząsów w Nigerii, które mogą być zapowiedzią większego trzęsienia ziemi. Pomimo tego budynki w Nigerii nie są projektowane z uwzględnieniem oddziaływań sejsmicznych. Niniejsza praca ma na celu przypomnienie o konieczności projektowania konstrukcji odpornych na trzęsienia ziemi z uwzględnieniem wiedzy o dynamice ziemi oraz historii trzęsień ziemi.