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Analysis and Design of a Residential Building against Flood Force in Floodplain Area: A Case Study of Ogbaru L.G.A of Anambra State, Nigeria.

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Abstract *: Flooding, which has been a perennial problem in Ogbaru has caused much havocs and difficulties to the inhabitants of Ogbaru community, such as destruction of farmlands, destruction of buildings, lives and properties. The aim of this study is to minimize the harm caused by flooding through design of flood proofed residential building against flood force.*
*A proposed residential building was designed against buoyance force and the result obtained showed that the dead load (structure weight) (2524.573KN) from the house is sufficient to prevent overturning from the buoyancy force (2499.33KN)***.** *The marginal difference between the two forces is not much. Therefore, dry flood-proofing should be limited in areas where flood velocities adjacent to buildings is greater than 1.524m per second during the design flood. It should also be noted that in as much as buoyance force will equalize hydrostatic pressures on the foundation walls, hydrodynamic and flood-borne debris impact forces will still apply*.
Keywords- Flooding, Dry flood-proofing, Buoyance force, Dead load, Flood velocity

1. Introduction

1.1 Background of the Study

Flood plain is the residual area outside of the floodway where the water velocities are less and flood protection and flood-proofing measures can be considered. In practical terms, the chance of flooding can never be eliminated entirely. However, the consequences of flooding can be mitigated by development of flood plain. Certain factor such as the effects of climate change cannot be brought under control. However, suitable actions are both possible and needed to begin to reduce the exposure and vulnerability to flood hazard of people and property and, thereby, enhance flood security. (De wrachien et al., 2010).

In Nigeria, Anambra State was tagged flood disaster zone. The National Emergency Management Agency (NEMA), (2012) reported that the 2012 flood in Nigeria was declared a national disaster as it affected over 2.3 million people and killed over 363 people. Some Nigerian cities were swept off by the flood and affected 34 out of 36 states of the federation including Anambra state which was ranked as the worst hit. According to NEMA (2012), at least 68 people were killed in Plateau State in central Nigeria and also 25 bodies found in Benue River after the flood while properties were also lost. These occurrences show that flooding is affecting the national populace and economy; yet mitigation measures are still poor as affirmed by Anambra State Ministry of Environment (ANSEMA) (Efobi and Anierobi 2013). Anambra State is situated at the lowest point of the River Niger and as such is flood prone. These periodic flooding that occur on rivers, form a surrounding region known as flood plain and it is on this plain that economic activities of these people take place. This was the reason why Anambra State was greatly and badly affected by flood (Sun News,2012). The affected local government areas were Anambra West, Anyamelum, Anambra East and Ogbaru. These local governments were highly submerged in water. The impacts of such floods have been severe due to the number of human populations exposed following the attractions of coastal areas for economic and social reasons.

The most effective flood mitigation method is relocation but when this method is not feasible or cost-effective, flood-proofing may be an appropriate alternative. Flood-proofing techniques usually require either dry measures or wet-flood techniques to secure thorough protection.

1.2 Aim and objectives

The aim of this study is to design residential buildings against flood force in Ogbaru L.G.A. This will be achieved through the following objectives:

i. To identify the causes of floods in Ogbaru Local Governmemt Area in 2012.
ii. To compare dead load of a proposed building with buoyance force to prevent overturning of the building

2. Literature Review

Ogbaru community suffered most of the floods on account of their relatively low and flat disposition with slope angles of

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1º-3º (Ajaero and Mozie, 2014). Some of these communities are flooded for over 8 months of the year as a result of their low lying relief and location at the point where the River Niger seem to have one of its greatest discharge rates. The overflow of the river bank by the water from the river into the overlying plain is therefore an essential geographical feature of this location. The relief is a plain land of heights ranging from 0 – 50m and characterized by swampy conditions as a result of its alluvial mud content. Its geology is mainly alluvium while the River Niger and Ulasi River which is its major tributary constitute the two major rivers in the area. However, there are local creeks and ponds all over its landscape. The vegetation is a mixture of fringing forests along the banks of the river Niger and guinea savannah in the hinterland (Ezenwaji et al., 2014). The aquifers are quite shallow with average elevation of 25m above sea level. The climate lies within the tropical rainy climate zone {AF} in accordance within Koppens climate classification and under the influence of tropical continental (CT) and tropical maritime (MT) air masses with the convergence zone (ITCZ) shifting seasonally with pressure belts and isotherms.

The continued release of excess water from dams has been a major reason for flooding in Ogbaru. With River Niger overflowing, some dams also overflowed and if not for the steps taken by the authorities, the result would have been more devastating (Nwilo, 2013). According to Ezeokoli et al (2015), in 2012, Nigeria recorded a nationwide flood disaster. The floods occurred due to excessive rainfall between May and October, 2012. This increased water supply from the Niger and the Benue and thereby causing an increase in river level along the Niger. In addition, 2012 flooding occurred due to the release of water from the reservoir behind the Lagio Dam in the Republic of Cameroon. The reservoir held 7.70km^3 of water which was released to avoid the dam failure (NEMA, 2012). Also, in conformity with flow theory, the high water level in the brain channel of the Niger caused a damming of the outflow from the Anambra basin. It also caused a reflux and the subsequent damaging floods on the Anambra plains with water level rising up to 10 metres above the normal rainy season levels (Ajaero and Mozie, 2014).

The primary, secondary and tertiary effects of flood were called into play in the last flood disaster in Ogbaru. There were physical damages to structures, social dislocation, contamination of clean drinking water, spread of water-borne diseases, shortage of crops and food supplies, death of non-tolerant tree species, disruption in transportation system, serious economic loss and psychological trauma. According to Ajaero and Mozie (2014) about 96.70% of Ogbaru L.G.A was affected, 81.70% was very severely damaged and in about 36% the flood comes yearly and comes after a long spell of safety in about 64%. Huge sum of money meant for other purposes were spent to cushion the effect of the natural disaster

Other impacts of flood include physical injuries, social disorders, homelessness, food insecurity, economic losses (mainly through destruction of farmlands, social and urban infrastructure) and economic disruption as is evidenced in some communities that was submerged by flood in Anambra State. The number of Internally Displaced Persons (IDPs) ran into thousands with an estimated 10,000 homes fully or partially submerged (Oseloka, 2012). The situation for these communities remained dire and very bleak. Homes, farmlands and properties estimated at billions of naira were lost; there were minimal loss of lives, with only few casualties, through the early warning and proactive intervention of the Anambra State Government and SEMA (Don Okpala, 2013).

2.1 Flood-proofing of residential buildings

Two basic flood-proofing methods are dry flood-proofing and wet flood-proofing. Dry flood-proofing refers to structural changes or measures applied to those portions of buildings located below the design flood elevation to keep the enclosed space completely dry during a flood. If done incorrectly, the walls may collapse, causing more damage than if the structure were allowed to flood in the first place. This type of method includes building on fill, surrounding buildings with flood-proof walls or berms, making lower levels of buildings water-tight and elevating structures above design flood-levels on some kind of support (e.g. stilts) provides reliable protection against flood damage. this method uses land efficiently, does not raise the flood-level and has minimal adverse effects on flood flows. this alternative requires careful design to prevent damage to supports from floating debris. it also allows sufficient space for flood waters to pass underneath the structure (www.odpem.org.jm).

Irrespective of type of flooding that occurred, either from storm surge, riverine flooding, or urban flooding, the physical forces of the floodwaters which act on the structure are generally divided into three load cases. these load cases are hydrostatic loads, hydrodynamic loads, and impact loads. these load cases can often be exacerbated by the effects of water scouring soil from around and below the foundation. the hydrostatic loads are both lateral (pressures) and vertical (buoyant) in nature. the lateral forces result from differences in interior and exterior water surface elevations. as the floodwaters rise, the higher water on the exterior of the building acts inward against the walls of the building. similarly, though less common, a rapid drawdown of exterior floodwaters may result in outward pressures on the walls of a building as the retained indoor floodwater tried to escape (www.fema.gov). The equation for buoyance force
Is given as

$F_{buoy} = \gamma w$ (Vol)-----------------------equation 2.1

$F_{buoy} = \gamma w$ (AH)------------------------equation 2.2

Where:

F buoy = vertical hydrostatic force resulting from the displacement of a given volume of water(kg)

γw = specific weight of water (9.807KN/m^3)

AH = Volume of floodwater displaced by a submerged object

3. METHODOLOGY

3.1 introduction

Ogbaru Local Government Area of Anambra State is one of the 21 Local Government Areas that make up the State. According to the 2006 national census, the LGA has a population of 221,879 (National Population Commission (NPC), 2006). The area is surrounded by the River Niger in such a way that most of the communities are located at the bank of the River (see Figure 3.1). The towns that make up the Local Government include Atani, Akili-Ogidi, Akili-Ozizor, Amiyi, Mputu, Obaogwe, Ohita, Odekpe, Ogbakugba, Ochuche Umuodu, Ossomala, Ogwu-aniocha, Umunankwo, Umuzu, Okpoko, and Ogwu Ikpele with headquarters at Atani. To the north, the study area is bounded by Onitsha South Idemili LGAs in Anambra state, to the south it is bounded by Imo and Rivers States, to the east it is bounded by Ekwusigo and Ihiala LGAs in Anambra and to the west it is bounded by River Niger and Delta State. It is located between latitudes 5° 42' N and 6° 08' N and longitudes 6° 42' E and 6° 50' E. The average climatic conditions are wet (from March to October) and dry (from November to February) seasons. The highest rainfall is recorded from June to September. The average annual rainfall ranges between 1800 mm and 2000 mm. The temperature pattern has mean daily and annual temperature as 30°C and 27°C respectively, while the average relative humidity ranges between 60-70% and 80-90% in January and July respectively (Monanu, 1975a, 1975b). The study area floods during the rainy season and dries up completely at dry seasons, though the flood remains for a number of times before receding. The plains suffered most of the floods on account of their relatively low and flat disposition with slope angles of 1º-3º (Ajaero and Mozie, 2014)

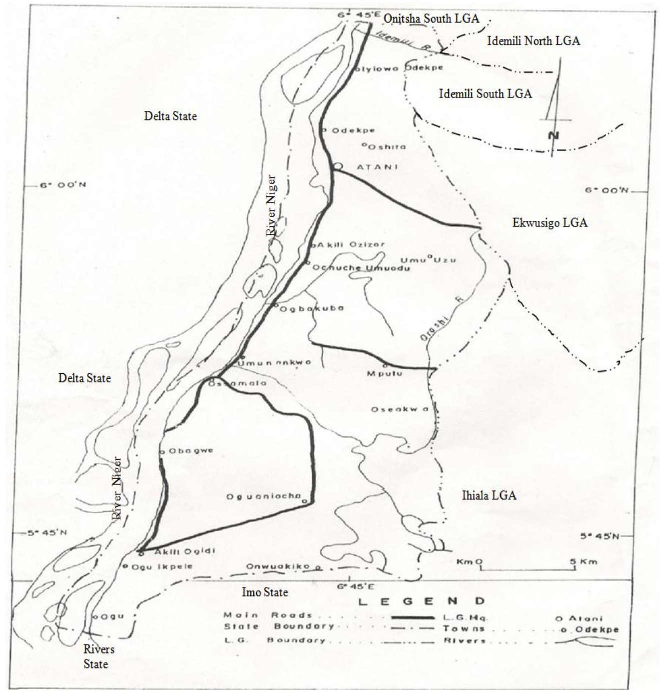

Figure 3.1: Map of Ogbaru L.G.A (Study Area)

Figure 3.2: Submerged Buildings In Ogbaru L.G.A

In this case study, the house in Figure 3.2 is located in a designated floodplain and is subject to a flood 1.219m in depth above ground level; the houses in this area should be redesigned for flood-proofing. For example, buildings can be raised above the design flood level by placement of fill; stilts or piles used to elevate the structure; and building utilities can be located above the flood level (figure 3.3).

Figure 3.3: Flood proofed dwelling

(www.unisdr.org)

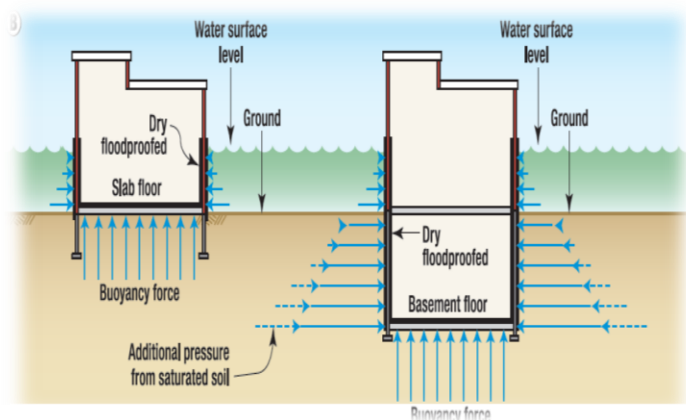

Fig 3.4: Designed Proposed flood-proofed dwelling for the case study (www.fema.gov)

3.2 Analysis and design of proposed flood proof Dwelling
3.2.1 Design Information

Wood-frame house 9.144m x 18.288m; and

Area of Gable wall :45m^2 with 4:12 slope.

Extended foundation walls are to be constructed of 0.203m-thick concrete masonry units.

The existing footing is 0.6096m wide by 0.3048m thick concrete reinforced with steel bars

Local regulations require an additional 0.30m of freeboard above the 100-year flood elevation;

Per International Residential Code (IRC) and American Society of Civil Engineers (ASCE) 7:

1. Design flood elevation (DFE)

2. Flood-proofing design depth

3. Total vertical flood load due to buoyancy

4. Vertical loads on the house (excluding buoyancy force)

5. Total structure dead weight

6. Is the total structural dead weight sufficient to prevent flotation of the house from the buoyancy force during a flood event?

DFE = FE + f --------------------------equation 3.1

The flood depth *(H)* is defined as the difference between the flood protection level (DFE) and the lowest eroded ground surface elevation *(GS)* adjacent to the building (see Equation 3.2)

H = DFE – GS----------------------------equation 3.2

$F_{buoy} = \gamma w$ (AH)---------------------------equation 3.3

Where:
γw = specific weight of water (9.807KN/m^3)
AH = Area × Height

Where:
Area = (length and width = 9.144m and 18.288m respectively).

There equation 3.3 becomes:

$F_{buoy} = \gamma w \times L \times W \times H$-------------------equation 3.4

4. Analysis, Results and Discussion

(1) To find the DFE, use Equation 3.1

DFE = 1.219m + 0.305m = 1.524m

(2) To find the flood-proofing design depth over which flood forces will be considered, use equation 3.2:

H = 1.524m – 0m = 1.524m
F_{buoy} = 9.807KN/m^3×9.144m × 18.288m × 1.524m
= 2499.33KN

(3) The vertical loads can be determined as follows:

Calculate Structure Weight by Level

- Tabulate Dead Loads by Floor (based on ASCE 7-10, Table C3-1)

Roof: 2x6 Top Chord and 2x4 Web and Bottom
Shingles – Asphalt – 1 layer: 0.096KN/m^2
Felt: 0.034KN/m^2
Plywood – 32/16–1/2 in.: 0.072KN/m^2

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Trusses @ 16 in. o.c.: 0.239KN/m^2
Total = 0.096KN/m^2+0.034KN/m^2+0.072KN/m^2 + 0.239 KN/m^2 = 0.441KN/m^2

First Floor Ceiling:
Insulation – 16 in. of fiberglass: 0.383KN/m^2
1/2 in. plywood: 0.072KN/m^2
1/2 in. plaster and lath: 0.479KN/m^2
Misc., heating, electrical, cabinets: 0.096KN/m^2
Total = 0.383KN/m^2 + 0.072KN/m^2 +0.479KN/m^2 +0.096KN/m^2 = 1.03KN/m^2

First Floor:

Oak Floor: 0.192KN/m^2
Subfloor – ¾ in. plywood: 0.144KN/m^2
Joists (2x12): 0.192KN/m^2
Insulation – 10 in. fiberglass: 0.239KN/m^2
Misc., piping, electrical: 0.144KN/m^2
Gypsum ceiling – 1/2 in.: 0.120KN/m^2
Total = 0.192KN/m^2+ 0.144KN/m^2+0.192KN/m^2+ 0.239 KN/m^2+ 0.144KN/m^2+0.120KN/m^2 = 1.031KN/m^2

Walls:
Interior – wood stud, plaster each side: 0.958KN/m^2
Exterior – 2x4 @ 16 in. o.c., plaster insulation, wood siding: 0.862KN/m^2
Lower Level – 8 in. masonry, reinforcement at 48 in. o.c.: 2.202KN/m^2

Determination of the Total Weights by Level
Roof: Using the roof overhang of 0.6096m
Surface Area= (4.819+0.6096m)(18.288 +0.6096m) (2)
=(5.4286m) (18.8976m) (2)
= 205.169m^2
Projected area = [4.572m+ 0.6096)($\frac{4.572}{4.819}$)] (18.288 +0.6096m)(2) = (4.9160) (18.8976) (2)
= 185.801m^2.
Shingles: (205.169m^2) (0.096KN/m^2 = 19.696KN
Felt: (205.169m^2) (0.034KN/m^2) = 6.976KN
Plywood:(205.169m^2)(0.072KN/m^2) = 14.772KN
Trusses: (185.801m^2) (0.239KN/m^2) = 44.406KN
Gable end walls: (45.72m^2)(0.862KN/m^2) =39.411KN
Total = 19.696KN +6.976KN + 14.772KN + 44.406KN + 39.411KN
= **125.261KN** for roof weight.

First Floor Ceiling:
Area = (18.288m) (9.144m) = 167.225KN

Insulation : (548.64)(0.383KN/m^2) = 210.129KN
plywood: (548.64)(0.072KN/m^2) = 39.502KN
plaster & lath:(548.64) (0.479KN/m^2)=262.799KN
miscellaneous(548.64)(0.096KN/m^2) =52.670KN
Total=210.129KN+39.502KN+262.799KN +52.60KN = **565.1KN** for the first floor ceiling

Walls:
Exterior: (54.864m) (1.219m) (0.862KN/m^2) = 57.650KN
Interior:(47.854m)(1.2192m)(0.958) = 55.870KN
Total = 57.650KN + 55.870KN = **113.520KN** for the wall

Calculating the subtotal for roof, first floor ceiling and wall
W_1 = 125.261KN + 565.1KN + 113.520KN = 803.881KN

First Floor Including Lower Level: Each of the components has the following area:
Area = (18.288m) (9.144m) = 167.225KN
Floors:
Oak Floor: (548.64m^2)(0.192KN/m^2) =105.331KN
Subfloor: (548.64 m^2)(0.144KN/m^2) =79.004KN
Joists: (548.64 m^2)(0.192KN/m^2) = 105.339KN
Insulation:(548.64 m^2)(0.239KN/m^2)=131.125KN
Miscellaneous: (548.64 m^2)(0.144KN/m^2) =79.004KN
Total = 105.331KN + 79.004KN + 105.339KN = 131.125KN + 79.004KN = **499.803KN** for the floor

Ceiling:
(548.64 m^2) (0.1197KN/m^2) = **65.672KN** for the ceiling

Walls:
Exterior: (54.864m) (1.2192m) (0.862KN/m^2) = 57.649KN
Interior: (47.854m) (1.2192m) (0.958KN/m^2) = 55.893KN
Lower level above proposed dry flood proofed slab: (54.864m) (2.743m) (2.203KN/m) =331.481KN
Weight of water per square foot of masonry wall:(0.203m) (2.988 KN/m^3) = 0.607KN/m^2
Lower level below proposed dry flood-proofed slab: (54.864m)(0.4572m)(2.203KN/m^2- 0.607KN/m^2) = 40.034KN
Total = 57.649KN+55.893KN+331.481KN+ 40.034KN = 485.057KN for the walls

Footings:
(54.864m)(0.6096m)(0.3048m) (45.72m - 19.02m) = **272.186KN** for footing

Slab:
(548.64m) (0.101m) (7.182KN/m^2) = **397.974KN** for slabs
Calculating the subtotal for the floor, ceiling, walls, footing, and slab:
W_2=499.803KN+65.672KN+485.057KN +272.186KN +397.974KN =1720.692KN

The total dead load of the structure can be found by adding the two above subtotals:

$\mathbf{W = W_1+W_2 = 803.881KN + 1720.692KN = 2524.573KN}$

To determine if the dead load (structure weight) from the house is sufficient to prevent overturning from the buoyancy force, the buoyancy force was compared to the structure weight:

$\mathbf{W \geq F_b}$

$\mathbf{2524.573KN \geq 2499.33KN}$ **(GOOD)**

Therefore, the structural weight is enough to prevent floatation of house during design flooding events. Additionally, in the case that the dead weight of the elevated structure could resist the buoyancy forces, the new slab would have to be designed to transfer buoyancy loads to exterior walls without cracking. Buoyancy forces control the building (if dry flood-proofed) during a flooding event unless structural measures, such as floor anchors or additional slab mass, or non-structural measures such as allowing the lower level to flood, are utilized to offset/equalize the buoyancy forces.

The calculation of buoyancy forces and comparison with structure weight is a critical determination of this problem. While buoyancy of the first floor is not an issue (since it is elevated 1.524m above the DFE), buoyancy of the entire structure (slab, foundation walls, and superstructure) must be checked if dry floodproofing is being considered for the lower level (www.fema.gov/hazard/flood/pubs/lib259.shtm)

5. Conclusion

Management of activities within the flood prone area can significantly reduce flood damages to existing development and prevent the amount of damages from rising in the future. The most desirable approach is to prohibit new development in the flood plain and to flood proof existing structures, or to replace the existing development by alternative usage of the land. However, where the amount of present development is substantial or the flood plain is essential for the production of food or other key economic activities, alternate strategies such as flood proofing and protection can be considered. Any new construction permitted in the flood plain should be flood proofed to reduce future damages. Building codes can be developed that minimize flood damages by ensuring buildings are located above the design flood elevation.

6. Contribution of the Study

This study will serve as a stepping stone for further designs and analysis of residential buildings to be carried out against flooding. Building codes can then be developed based on these future researches. This will help in minimizing the impact of flood damages by ensuring that buildings are located above the design flood elevation.

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