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Flood Resilience Measures in Buildings on the Flood-plains of Ogbaru, Anambra State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author FOE initiated the idea, designed, carried out data acquisition and compiled the first draft of the manuscript. Author KCO was responsible for supervising every stage of the research and proof reading while author SUO managed the literature review, data analysis and proof reading. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The study evaluates the flood resilience measures in buildings on flood-plains of Ogbaru, with a view to establishing the extent of its incorporation into the design and construction of Buildings.
Study Design: It was a survey research, questionnaires were distributed to heads of the selected households and building practitioners in the study area. Likewise, physical observations were carried out to substantiate the findings of the questionnaire survey.
Place and Duration of the Study: The study was conducted in Ogbaru Local Government Area, Anambra State, Nigeria for a period of 2 years.
Methodology: Being a survey research, data were collected through structured questionnaire administered to the selected building construction practitioners and occupants in Ogbaru. In addition, interviews and direct observation survey were conducted to substantiate the validity of the questionnaire survey. Accordingly, a total of four hundred and (400) questionnaires were distributed and a total of two hundred and ninety-three (293) questionnaires were completed and returned. This

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corresponds to a response rate of 73.3%. Data collected were analyzed using mean score, standard deviation, pearson product moment correlation (PPMC) techniques and z-test.
Results: The study found out that the flood resilience measures are not largely incorporated into the design and construction of buildings. The flood resilience measures currently in use are few and includes raised building floor level or platform, use of concrete floor and tiling, use of embankments, re-routing flood water channels, building walls and floors with none/low permeability materials, raised kitchen appliances and low walls or barriers between streetscape, Also, advanced or sophisticated flood resilience measures such as Automatic window opening panels (flood inlets), water sensors within and outside buildings and hybrid design are rarely used in the study area.
Conclusion: The study concluded by recommending that flood resilience measure should be incorporated into the development/ construction of building within the study area. Also, newer and sustainable flood resilience measures/technologies should be made available and affordable in the study area.

Keywords: Flood; flood-plain; buildings; flood resilience; Ogbaru.

1. INTRODUCTION

Built environment globally is vulnerable to natural disasters, which are increasing due to the impact of socio-economic development, land-use development and changes in climate condition [1]. Recently the impacts of disaster particularly flooding have continued to gain momentum globally because of the number of people and buildings affected annually [2]. Consequently, whenever disaster occurs, built environment (particularly, buildings) generally is affected most. Based on this, [3] stressed that "the built environment bears the brunt of the damages from disasters of all sort. Because most building cannot be moved elsewhere even if the imminent disaster could be predicated accurately [3]. Therefore, the most visible and striking effects of any major disaster besides human casualties, is massive destruction of houses/buildings [4 - 6]. Such buildings and infrastructural systems easily destroyed by flood events are not resilient [7] and need to be.

Resilience according to Mc Allister [7] means the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents. From the Built Environment (BE) perspective, [8] defined resilience as sustainable measures that can be incorporated into the building fabric, fixtures and fittings to reduce the impact of floodwater on properties and allows easier drying and cleaning, ensures that the structural integrity of the buildings are not compromised and reduces the amount of time within which the building can be re-occupied after a disaster. On the other-hand, flood resilience could be seen as the construction of a building in such a way that though flood water may gain access into the building but its impact is reduced (i.e. no permanent damage is caused, structural integrity is maintained and drying and cleaning are facilitated [8]. Rasmus [9] defined resilience as the ability of a system to withstand shock through absorption and adaptation. Equally, [10] defined resilient buildings as buildings designed and constructed in such a way as to reduce the cost and time required to reinstate the property should it be flooded. On the other hand, resilient community according to QFMP [11] is the one that possesses the capacities, skills and knowledge that enable it to prepare for, respond to, and recover effectively from a disaster and adapt positively to a changing environment. Thus, it is a community that confronts its risks/vulnerabilities and enhances its capacity to address their vulnerabilities to hazards [11]. Accordingly, any resilience measures should ensure that the building can be occupied safely over its proposed lifetime taking into consideration climate change [8].

Conversely, extreme flood event has become a regular phenomenon within the floodplains of Ogbaru, Anambra East, Anambra West and Ayamelum local council area of Anambra state. Flood data in Anambra state indicate that the intensity of the flooding in these areas is same but the extent of the destruction in terms of infrastructural, agricultural and socio-cultural activities differs [12]. This situation has caused widespread devastation and destruction of properties worth billions of naira [13]. Furthermore, in Ogbaru, extreme flood events have continued to wreak havoc every rainy season which were not unreported (see plate 1-4).

The extent of damages on buildings in plate 1-4, indicate that flood resilience measure was not


Plate 1: Partially collapsed building


Plate 2: Collapsed mud house


Plate 3: Collapse foundation


Plate 4: Separated wall

properly integrated into the design and construction of buildings in Ogbaru. consequently, it cost so much resources and time to reinstate these buildings for human habitations. However, those who could not afford such, continued to dwell in such building affected by flood disaster with their family. This scenario, seriously entails a further disaster in waiting. On this note, [3] suggested that the design and construction of human settlements must consider the natural and man-made disaster confronting them. Put differently, means that buildings should be designed and constructed to be resilient and sustainable. Based on this, this study evaluates the flood resilience measures incorporated into the design and construction of buildings in floodplains of Ogbaru.

2. LITERATURE REVIEW

2.1 Flood Resilient Buildings & Measures

Achieving flood (disaster) resilience in building could be seen as the construction of a building in such a way that although flood water may enter the building but its impact is reduced (i.e. no permanent damage is caused, structural integrity is maintained and drying and cleaning are facilitated) [8]. The principle is simple – plan and develop properties, buildings and structures so that they are safe from disaster (flooding) from the outset without compromising the safety of other properties [14]. Building must be resilient in terms of avoiding failures and losses, as well as responding appropriately to the event that challenge its boundary condition (i.e. they should be able cope, adapt, or reorganize to events that stretch its boundaries) [15], [16]. Generally, resilient buildings are characterized as buildings that allow floods, but aimed at minimizing flood impacts and maximizing recovery rates, for all possible flood waves [17]. Therefore, using architecture to increase the resilience of a community requires not only creating programs that focus on existing functions and making them more adaptable, but also creating new functions to increase community adaptability [18]. Flood resilient building/ measures according to Batica [1]; Proverbs and Lamond [19] are designed to achieve:

i. To limit financial impact on flood victim or their insurer by reducing damages to contents and building fabric.
ii. To reduce time of reinstatement of property by allowing communities to return to normality quickly in the aftermath and;

iii. To prevent flood damages and to save lives.

Ezeabasili and Okonkwo [20] studied climate change impacts on the built environment in Nigeria and suggested ways of achieving floods resilience during the design and construction of building in order of their priority as: Citing, Exceed minimum floor levels, Consider multi-storey construction, Design and construct buildings for flooding occurrences, Use water-resistant materials, Design to ensure water can easily escape once flooding has subsided, Raise flood awareness and preparedness with building occupants, including designing and providing information about access routes. Build a levee or flood wall around the building, and; Raise flood awareness and preparedness with building occupants .

Furthermore, [1] carried out a research on "Methodology for flood resilience assessment in urban environments and mitigation strategy development" using survey approach. The outcome of the research discovered that, the specific characteristics/function of resilient buildings are: First function is to prevent water to enter the property and Provides the possibility for occupation of urban function.

Equally, [21] carried out a research "Recommended Residential Construction for Coastal Areas in US" using mix design approach and observed that buildings are considered to be flood resilient if the following are true after a design-level event: The building foundation is intact and functional, The building envelopes are structurally sound and capable of minimizing penetration of wind, rain, and debris, The lowest floor elevation is high enough to prevent floodwaters from entering the building envelope, The utility connections remain intact or can be easily restored, The building is accessible and habitable, and any damage to enclosures below the lowest floor does not result in damage to the foundation.

To [22] some of the characteristics of Flood Resilient Property are: The house is designed to resist water up to 600mm in depth after which water is allowed to enter into the property to reduce pressure on the structure; Automatic opening window panels (flood inlets) are triggered by localised sensors to allow a controlled inundation of flood water into the property; Flood resistant doors automatically protect against water entry; Internal walls are water resilient, using materials which will allow fast recovery: concrete block partitions, lime plaster or magnesium oxide board as finishing – skirting is sealed with an internal cavity membrane; and Potential to connect the main sounder to an automated call system / emergency authorities Flood Emergency Kit to be stored on first floor. In addition, [8], [23] made the following suggestion as regard flood resilient buildings:

a) Robust materials and finishes should be used.
b) Finishes can be designed to be removable or sacrificial and easily replaced in the zone affected by flooding.
c) Special vent covers can be used to close ventilation bricks to prevent under floor voids and cavities becoming flooded.
d) Solid walls finish render in cement rendering systems or tiling, at least up to dado level should be used in preference to timber stud partitions finished in plaster board.
e) Solid concrete floors are preferable to suspended floor construction as they can provide an effective seal against water rising up through the floor, provided they are adequately designed.

Of all this, [10], [23] observed that "the most important measure of reducing the impact of flooding is to raise the minimum floor level of the property or development above expected flood levels. That is, insisting that all habitable rooms/spaces within residential accommodation be raised above the height of the design flood level or raise land levels to a point at which the ground level is effectively above the flood design level. Other flood resilient measures in shown in Table 1, 2 and 3 respectively. Table 1 discussed acceptable materials & unacceptable materials for flood resilient buildings established by survey carried out by [24] in 2015. Table 2, discussed Material Suitability for Building Components for flood resilience by Wingfield et al. [25] and Table 3 discussed flood resilient Measures with respect to different flood depth. Table 1, 2 and 3 shows that concrete, reinforced concrete and engineering brick is most suitable material for structural component of building with respect to any form of flooding. Timbers or woods should be avoided for structural elements but if it must be used it should be treated properly.

Table 1. List of acceptable materials and unacceptable materials for flood resilient buildings

Building element/component	Materials to use	Materials to avoid
Structural Floors	1)Concrete 2)Steel 3)Marine grade or preservative treated plywood 4)Treated or naturally decay resistant lumber	1) Engineered wood or laminate flooring 2) Oriented-strand board 3) Exterior grade or edge-swell resistant headers and beams 4) I-joists
Floor finishes	1)Ceramic, porcelain or clay tiles 2)Terrazzo or terrazzo tiles 3)Vinyl tile or sheets	1)Engineered wood or laminate flooring 2)Carpeting 3)Wood flooring 4)Cork
Structural Wall and Ceiling Materials	1)Concrete 2)Brick face 3)Cement board, fibre-cement board 4)Pressure-treated lumber 5)Solid, standard, structural lumber 6)Aluminium studs 7)Closed cell insulation 8)Paperless gypsum board	1) Fiberglass insulation 2)Paper-faced gypsum board 3)Oriented-strand board 4) Green-board
Wall and Ceiling Finishes	1)Glass 2)Metal cabinets or doors 3)PVC board and trim 4)Latex or epoxy paint 5)Stainless steel or galvanized steel hardware	1)Wood cabinets and doors 2)Particle board cabinets and doors 3)Standard wood finish trim 4) Non-latex pain 5)Wallpaper 6)Plaster 7)Cork

Source: COH, (2015)

Table 2. Summary of material suitability for building components

Component	Most suitable	Suitable	Unsuitable
Flooring	Concrete, pre-cast or in situ	Timber floor, fully sealed, use of marine plywood.	Untreated timber Chipboard
Floor Covering	Clay tiles Rubber sheet floors Vinyl sheet floors	Vinyl tiles Ceramic tiles	
External Walls - tomax flood level	Engineering brick Reinforced concrete	Low water absorption Brick	Large window Openings
Doors	Solid panels with waterproof adhesives Aluminium, plastic or steel	Epoxy sealed doors	Hollow core plywood doors
Internal Partitions	Brick with waterproof mortar Lime based plasters	Common bricks	Chipboard Fibreboard panels Plasterboard Gypsum plaster
Insulation	Foam or closed cell types	Reflective insulation	Open cell fibres
Windows	Plastic, metal	Epoxy sealed timber with waterproof glues and steel orbrass fittings.	Timber with PVA glues andmild steel fittings

Source: Wingfield, (2005)

Table 3. Flood resilient measures listed with respect to forms/characteristics of flooding

Measure	Flood depth	Permanent/temporary	Flood type
Raise building level (floor level in the house)	<0.3m	Permanent	Flash floods, river floods, low infrastructure capacity
SUDS (Sustainable Drainage Systems)	-	Permanent	Flash floods, river floods, low infrastructure capacity
Re-routing flood water with channels		Permanent	Flash floods, river floods, low infrastructure capacity
Free standing barriers	<1 m	Temporary	Flash floods, river floods, low infrastructure capacity
Free standing barriers	<1 m	temporary	Flash floods, river floods, low infrastructure capacity
Periphery walls, gates		temporary	
Door guards and ventilation opening covers	<1 m	temporary	Flash floods, river floods
Flood skirts	<1 m	temporary	Flash floods, river floods, low infrastructure capacity
External doors	<0.6m	permanent	Flash floods, river floods, low infrastructure capacity
Cellar tanking	<0.6m ,	permanent	Flash floods, river floods, low infrastructure capacity
Concrete floors		Permanent	All flood types
Ceramic tile floors		Permanent	All flood types
Internal doors and walls		Permanent	All flood types
Raised electrics, tv and communication devices		Permanent	All flood types
Raised kitchen appliances		Permanent	All flood types
Stainless steel kitchen		Permanent	All flood types
Double check valves for water distribution points		Permanent	All flood types

Source: Batica, (2015)

3. METHODOLOGY

The population of this study constitutes the local/residents, construction professionals, disaster management agencies and building development control units (Anambra State Physical Planning Board -ANSPPB) in the study area. According to the 2006 National population and housing census, the population of persons in Ogbaru local council of Anambra State were 223,317 while the number of households in the area were 49,501 [26]. Using a population growth rate of 2.83% as recommended by National Population Commission for Anambra State [26], the population of Ogbaru LGA in 2017 was 303, 559.

Taro Yamani sample size method was employed to determine the appropriate sample size for this study.

Taro's formula is represented as:

i.e. $n = \frac{N}{1+N(e)2}$

Where "n" is the sample size, "N" is the population (303,559) and "e" is the level of confidence (i.e. 95%).

Thus, the sample size

$n = 303{,}559 / 1 + 303{,}599\ (0.05)^2 = 399.6$

Data were collected through structured questionnaire administered to the selected respondents or their representatives purposeful sampling technique was employed. 10 town of Atani, Akili-Ozizor, Mputu, Ohita, Odekpe, Ogbakugba, Ossomala, Ogwu-aniocha, Umunankwo and Okpoko, and out of the sixteen towns that make up the council area were purposefully selected because other towns could not be easily accessible as at the time of carrying out the field survey and must have been flooded in the past five years. 40 respondents which comprises of local and construction professional were randomly selected from each of the 10 selected towns. Furthermore, interviews and direct observation were conducted to substantiate validity of result of this study. In total, four hundred (400) questionnaires were distributed to respondents in Ogbaru. Out of this total, two hundred and ninety-three (293) questionnaires were completed and returned. This corresponds to a response rate of 73.3% (See Table 4). Data collected were analyse using mean score, standard deviation, pearson product moment correlation (PPMC) techniques and z-test.

4. RESULTS AND DISCUSSION

This section presents the results, analysis, discussions and findings of the data collected. Table 5 discussed the flood measures incorporated into buildings. Table 6 and Table 7 presented the result of the correlation test and z-test respectively.

The result in Table 5, shows that there is a general disagreement in the response of the households and professionals as regards flood resilient measures incorporated into the designs and construction. For instance, professionals agreed that Sustainable Drainage system, Re-routing flood water channels, Ceramic tile floors, and Building walls and floors with none/low permeability materials are flood resilient measures incorporated into buildings in Ogbaru while households disagreed to that. On the other hand, households agreed that Raised kitchen appliances and Low walls or barriers between streetscapes are flood resilient indicators/measures.

Consequently, the research measured the extent to which the opinions of these two groups are associated. In doing this, the research performed pearson product moment correlation (PPMC) techniques. The result is as presented in Table 6.

The correlation test result indicates that there is a significant association in average opinions of the households and those of the professionals. This shows that pooled analysis can be performed on the responses.

To evaluate the extent to which flood resilience measures are incorporated into the design and construction of buildings in the study area, the research performed one-sample z-test on table 5. The z-test result is shown in Table 7.

The z-test result (see table 7) with a statistic value of 0.01 and associated probability value of 0.986 > 0.05 indicates that flood resilience measures are not to a significant extent incorporated into the design and construction of buildings in the area.

On the hand, the result in table 5, shows that raised building level with a mean score of 4.09 ranked first for floor resilient measure integrated into buildings in the study area. Followed by sustainable Drainage system (3.26), concrete floors (3.52), re-routing flood water channels (3.06), Building walls and floors with none/low permeability materials (3.01), raised household utility (3.01), raised kitchen appliances (2.95) and Ceramic tile floors (2.82). On the other hand, Automatic window opening panels (flood inlets) with a mean score of 1.48 came least with respect to flood resilient measures in use in the study area (see table 5). Closely followed by external door sensors & internal ground level sensor (1.49), water sensors located outside the property and on entry points, linked to an internal remote alarm (1.61) and Hybrid design (use of stilts and floating principles) (1.70). Based on this, the research queried some of the locals and construction professional in the study area during the interview why newer and advanced flood resilience measures/technologies are not seldom in the study area? From their reaction it was discussed that these technologies are not readily available and when there are available they tend to be very expensive.

Table 4. Population distribution of questionnaire and percentage response

Categories	Number of questionnaires distributed	Number of questionnaires received	Percentage (%)
Professionals	300	205	68.3
Households	100	88	88
Total	400	293	73.3

Source: Field Survey (2018)

Table 5. Flood resilient measures incorporated into buildings in the study area

Flood resilient measures	Households		Professionals		$\bar{\bar{X}}$	$\overline{Std}$
	Mean	Std	Mean	Std		
Raised building level	3.54	1.395	4.64	0.618	4.09	1.007
Sustainable Drainage system	2.52	1.356	4.00	1.085	3.26	1.221
Re-routing flood water channels	2.86	1.352	3.25	1.340	3.06	1.346
Free standing barriers	2.31	1.131	2.53	0.859	2.42	0.995
Periphery walls/temporary flood barriers	2.21	1.100	2.53	0.952	2.37	1.026
Door guards and ventilation opening covers	2.29	0.933	2.07	0.993	2.18	0.963
Flood skirts	2.70	0.672	2.41	1.068	2.56	0.870
Cellar tanking	2.34	0.894	2.11	0.879	2.23	0.887
Concrete floors	3.13	1.560	3.92	1.051	3.53	1.306
Ceramic tile floors	2.43	1.466	3.20	1.198	2.82	1.332
Raised household utility	3.34	1.491	2.68	1.101	3.01	1.296
Raised kitchen appliances	3.22	1.542	2.68	1.101	2.95	1.322
Double check valves for water distribution / non-return valves on sewer	2.39	1.170	2.89	1.122	2.64	1.146
Building walls and floors with none/low permeability materials	2.44	1.259	3.57	1.298	3.01	1.279
Breakable and re-buildable structure	2.32	1.252	1.81	0.929	2.07	1.091
Create large space with thick concrete walls for flood waters	2.24	0.834	2.60	0.995	2.42	0.915
Stilts	2.19	0.918	2.44	0.765	2.32	0.842
Floating structures	2.08	0.820	1.95	0.890	2.02	0.855
Hybrid design (use of stilts and floating principles)	1.41	0.789	1.98	0.890	1.70	0.840
Low walls or barriers between streetscapes	3.03	1.409	2.42	1.224	2.73	1.317
Automatic window opening panels (flood inlets),	1.03	0.206	1.93	0.914	1.48	0.560
External door sensors & internal ground level sensor	1.02	0.127	1.96	0.842	1.49	0.485
Water sensors are located outside the property and on entry points, linked to an internal remote alarm	1.52	0.501	1.69	0.791	1.61	0.646
Inspection chamber fitted with anti-lift lid	2.56	0.713	2.17	0.803	2.37	0.758
Emergency rescue locations designated at ground and first floor levels	1.61	0.708	2.30	1.240	1.96	0.974
Flood Emergency Kit	1.79	0.929	2.70	1.409	2.25	1.169
Cluster Mean & Std. deviation	2.33	1.020	2.63	1.014	2.48	1.017

Source: Field survey (2018)

Table 6. Correlation test result

		Households	Professionals
Households	Pearson Correlation	1	.624**
	Sig. (2-tailed)		.001
	N	26	26
Professionals	Pearson Correlation	.624**	1
	Sig. (2-tailed)	.001	
	N	26	26

***. Correlation is significant at the 0.01 level (2-tailed); Source: Researcher Field Survey (2018)*

Table 7. z-test result

						95% confidence interval of the difference	
Mean values	Mean	Std. dev.	SE mean	z-stat.	p-value	Lower	Upper
	2.480	0.629	0.199	0.01	0.986	2.092	2.874

Source: Researcher's Field survey (2018)

5. CONCLUSION AND RECOMMENDATIONS

Flood disaster is gradually becoming a regular phenomenon in the study area. Adapting to flood events (i.e. flood resilience) is one of key measures in flood management. Because, flood resilience goes beyond maintaining equilibrium to persistence of systems in the face of unexpected change and disturbance. However, in the study area flood resilience measures are not largely incorporated into the design and construction of buildings. The measures currently in use are few and includes raised building floor level or platform, use of concrete floor and tiling, use of embankments, re-routing flood water channels, building walls and floors with none/low permeability materials, raised kitchen appliances, low walls or barriers between streetscape, use of ring-beam and sacrificial mass. Also, recent flood resilience technologies/measures such as Automatic window opening panels (flood inlets), water sensors within and outside buildings and Hybrid design (use of stilts and floating principles) are rarely used in the study area. Consequently, the extent of destruction particularly on buildings have been on the increase annually. Therefore, the study recommends that flood resilience measure should be incorporated into the development/ construction of new buildings within the study area. The existing building should be retrofitted using flood resilient materials and technologies. The key stakeholders/custodians of the built environment in the study area should source for newer and affordable flood resilience measures/technologies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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