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Environmentally-responsive design; A study of Makoko floating school building

Francis Ogochukwu Okeke [1*], Basil Chukwuemeka Chukwuali [2], Augustine Enechojo Idoko [3]

Department of Architecture, University of Nigeria, Enugu State, Nigeria

Abstract

Environmentally-responsive architecture is not a fixed ideal, rather an evolving concept to be redefined with projects. This design approach adapts well to the local climate, topographical features and available resources in terms of settlement pattern, building volume configuration, semi-open and open space arrangement, building materials and construction techniques. In view of these enormous benefits and, to manage climate change, deficiency of usable plots of land, large water percentage of the Earth surface and income level improvement; floating building designs are emerging as a strong and attractive alternative all around the world. Floating buildings are new paradigm of architecture compared with the preconception of building only on land. The study aims to x-ray this embryonic field of architectural practice and research with Makoko Floating school design as a case study. It adopts a descriptive research method that employed mostly secondary data and surveys the mechanism of floating homes, offering an innovative solution to its safety. The research results note that vernacular architecture effectively addresses particular adaptation difficulties posed by local conditions and its conclusion indicates that Environmentally Responsive architecture presents itself as a model for Sustainable Development

Keywords: Floating Building; Makoko; Environmentally-Responsive Architecture; Climate Change; Local Building Materials

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* Corresponding author. *E-mail address:* ogochukwu.okeke@unn.edu.ng

1. Introduction

Over reliance and wasteful consumption of man-made energy with rapid waning of natural resources, has paved way for a new environmentally responsive architecture which must be created to apply to contemporary social housing needs. It resulted from many years of pragmatic investigations to develop environmentally-responsive dwellings that adapts to local climate and geomorphology to suit occupants daily requirements. According to Simos, (2003) environmentally-responsive architecture is that architecture aimed at achieving occupant thermal and visual comfort with little or no recourse to non-renewable energy sources. This Responsive architecture measures real environmental circumstances (via sensors) so that structures can adapt responsively (via actuators) their form, shape, colour or character. eg. Climate adaptive building shell. (Marlovics, 2016). It seeks to extend and polish the architectural profession by enhancing the energy efficiency of buildings with responsive techniques (sensors / control systems / actuators) while also creating buildings that represent the present day's technological and cultural situations.

The process of creating sustainable buildings begins at the concept design stage of any given project, with well understood climate of the site and required indoor environmental conditions for the building typology, the architectural response can perform efficiently without losing out on innovation or its aesthetic quality. Consequently, the use of simple equations can help refine the design to enhance the indoor environment by natural means and even question the normally accepted standards. (Varun, 2008)

Responsive architecture has differentiated itself from other interactive design types by integrating smart and responsive techniques into the key components of the fabric of a building. For instance: by incorporating responsive technology into the building's structural system, architects have the capacity to directly link a building's shape to their environmental setting.

1.1. Motivation

The technique and architecture of buildings all over the world depends on the climatic boundary conditions, the culture and availability of raw materials within the locality. With the impact of rising sea level due to climate change resulting to flooding and loss of properties and lives in most waterfront and coastal communities of Lagos State such as Victoria Island, Lekki, Ikoyi, Ojo, Makoko etc, it has necessitated the need to find a sustainable solution. With this backdrop the research stems to;

- To establish facilities that would enforce embracing nature (water) rather than fighting it with reclaimed land and if possible turn it into a self-sufficient floating city.
- To bring about the development of various business infrastructures that would provide employment and improve the lives of residents of the surrounding areas.
- To create awareness of the gradual deterioration of the environment, the vulnerability of waterside areas to flooding and other issues of environmental concern.
- To explore a more cost effective solution to the overcrowding of the Lagos waterside as opposed to dredging and filling the sea to expand the land area.

2. Floating building

Floating building means a permanently moored floating building built on a flotation system and not intended for, or useable in, navigation. (MP, 2007) A floating building must have a floatation system which maintains an acceptable level of stability appropriate to the use or likely use of the building and which:

a. Will not be affected by minor impact;
b. is watertight; and
c. is capable of withstanding the most adverse combination of loads it is likely to be exposed to.

The basic characteristic of a floating building is that it is not supported by a firm foundation, but floats on water. Traditional foundations are therefore not required. The position of a floating home is permanently fixed in a horizontal direction, while it can flexibly follow vertical variations in water level. Floating buildings can have terraces that can be regarded as a small-scale version of traditional gardens. They are recognized in some countries as immovable real estate, because the building's position is fixed in a horizontal direction. Light and fireproof materials are used for the building and it would have its own bio-digester for wastewater treatment and solar capability. (Daiga, 2011) Floating buildings have environmental benefits such as

- insusceptibility to changes in sea level, and
- Minimization of disturbance to the ecology of the harbor or seabed.

They can be built off-site and then towed into location, minimizing disturbance to the building site. If the building is decommissioned, it can also be relocated elsewhere.

There are two types of floating homes, permanently floating homes and homes that float only when flood waters swell, but sit on the ground during the dry season. The base of a floating structures consists of a floating mechanism that secures the building's buoyancy. The bottom level of the entire construction should be at least 1 meter from the water bottom in order to maintain favorable water quality conditions. It is essential that a floating building never touches firm ground, because the construction is not designed for such conditions. The floating mechanism that is positioned at the basis of the floating structure can consist of high-density EPS (expanded poly-styrene) or a hollow, concrete structure.

Hollow space can be used for storage of light goods. Infrastructure connections to floating buildings should be designed so as to be able to flexibly cope with expected water level variations.

2.1. Kinds of flotation systems

various types of floating systems include; Log floats, solid Styrofoam encased in rubber, foam filled steel pontoons, positive concrete, concrete pontoons, concrete and foam, wood and foam, polyethylene shell with solid core polystyrene block molded inside, fiberglass and envirofloat.

3. Research methodology

The research methodology for the study is descriptive in nature. It is a review of Makoko floating school design using secondary data and it adopted the following data collection pattern. They include:

- Collection of data through the internet study medium, journals and Literature reviews
- Investigation and evaluation of other existing floating building models in Lagos and the world taking note of the waterline properties.

3.1. Background of study area

Makoko is a coastal town and Nigeria's oldest slum, situated on the shore of mainland Lagos in a tiny neighborhood across the 3rd Mainland Bridge. A third of the community is built on stilts along the murky Lagos lagoon and the rest is on the land. The community's waterfront portion is mainly harboured by individuals from Egun who migrated from Badagary and the Republic of Benin and their primary occupation is fishing. Like many such villages, the neighborhood is plagued by poverty. (*Lara,* 2016). Many of the structures that the people call houses rest on posts above the Lagoon. With the passage of time, the lagoon gradually split into series of informal waterways through which nimble young bodies maneuver taxi-canoes. From the columned architecture to the re-appropriation of found objects (like Portland cement bags, parboiled-rice sacks etc that double as roof shelters) to stereo-equipped canoes that serve as portable music boxes, Makoko's residents have adjusted completely to survive on water. (Jessica, 2015). Home to as plenty as 100,000 people, the favela labelled ' Venice of Africa ' — (a flourishing community of residents living their entire life on water and in the background of one of the biggest urban centers in Africa)— but absence of steady power supply, basic school facilities, numerous health hazards, adequate waste management and disposal systems are problems facing the slum. (Yomi, 2015)

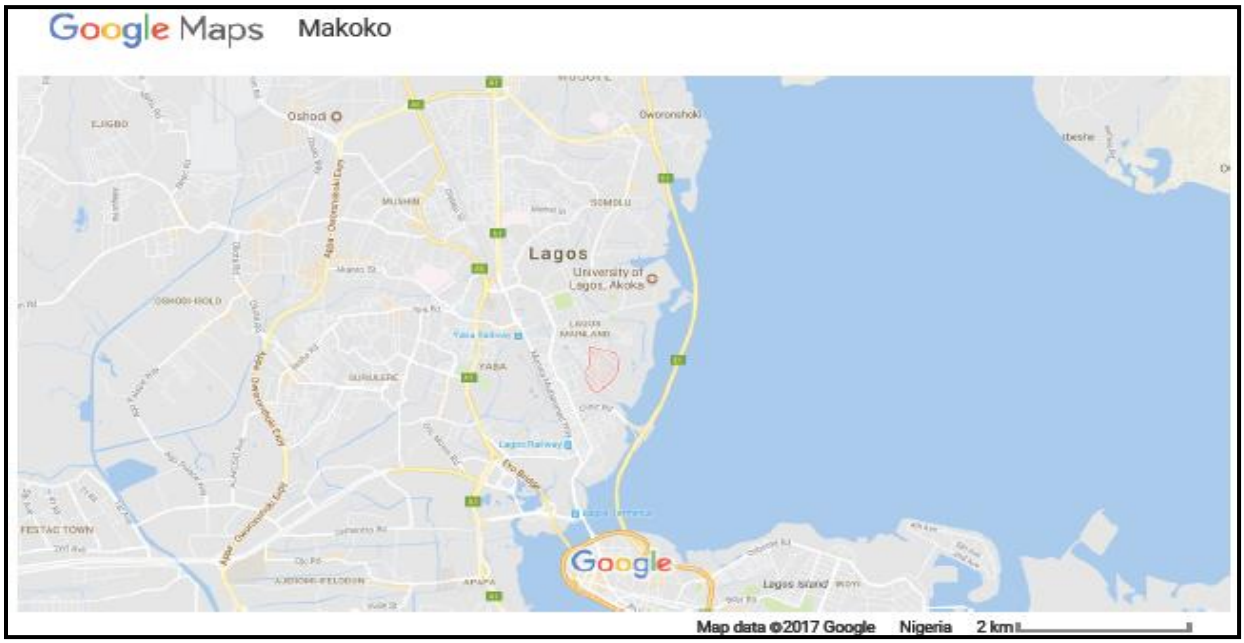

Figure 1. showing makoko area on map (source; google map)

Not until now Makoko has been served by one English-speaking primary school, built on uneven reclaimed land, surrounded by constantly changing waters. Like many homes in the area, this has rendered the primary school building structurally precarious and susceptible to recurrent flooding. Sadly, the inability of the building to effectively withstand the impact of increased rainfall and flooding has frequently threatened local children's access to their basic need – the opportunity of education. (Amy, 2014).

Only few years back, NLE Works, an architectural firm headed by Kunle Adeyemi, (one of Quartz's 2015 Africa Innovators), shot Makoko into prominence following the construction of the Floating School building.

Figure 2. showing makoko skyline (source; Iwan, Baan)

4. Findings

Half-building, half-boat, the floating structure provides teaching facilities for the slum district of Makoko, Prior to this the community had just one English-speaking primary school that regularly found itself under water. (Amy, 2014).The Makoko Floating School was constructed on a flotation platform made of barrels. It is a mere three storey structure, yet the facility is like a tower in the eyes of the local residents. It has been referred to as a beacon of hope, representing an opportunity to gain education. The Floating Building is of a vertical mixed use building category with a combination of different users within the same building. The structure is primarily used as a school and can accommodate up to a hundred pupil, even in bad weather conditions. It also function as a place of assembly, an events space, or whatever civic purpose the community wants. The floating structure withstands the tidal fluctuation and varying water level of the lagoon, making it invulnerable to flooding and storm disturbance.

4.1. Structural analysis

The 220m^2 A-frame or pyramid building is 10m high with a 10m x 10m base. The building has three levels. The 1st level is an open play area for school breaks and assembly, which also serves as a community space during after-hours of school. The 2nd level is an enclosed space for two to four classrooms, providing enough space for sixty to a hundred pupils. A staircase on the side connects the open play area, the classrooms and a semi enclosed workshop space on the 3rd level as depicted in figure 3 below.

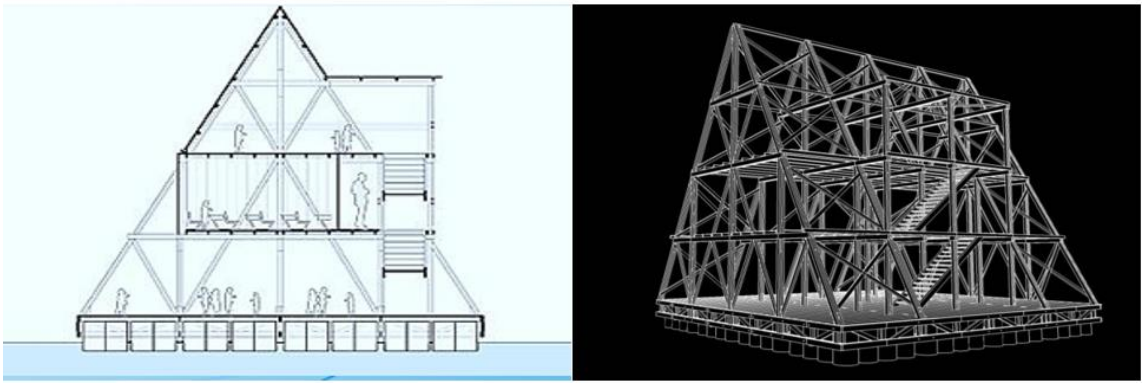

Figure 3. Structural configuration (source; NLÉ)

Built by a team of local residents, the structure was put together using wooden offcuts from a nearby sawmill and locally grown bamboo. The movable 'building' or 'watercraft' has a structurally endo skeleton frame that houses up to 100 adults at a time.

Figure 4. Structural framework, *(as community gather to test the building stability)* (source; www.dezeen.com)

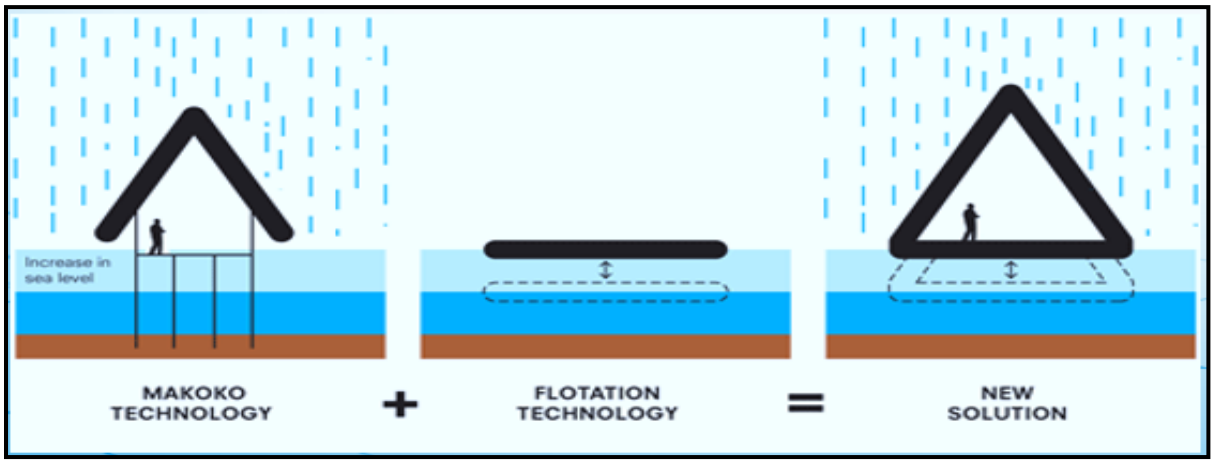

Figure 5. Design formula and Concept diagram (source; www.dezeen.com)

Figure 4, shows the triangular profile and building envelope that allows the building to accommodate three storeys whilst remaining stable over the water. The equilateral triangle is an ideal shape for a floating object on water due to its relatively low centre of gravity, which provides stability and balance even in heavy winds.

Figure 5, explains the conceptual design and principle behind the floating structure that enables it adapt to the tidal changes and varying water levels, making it invulnerable to flooding and storm surges. It rests on a base made of 250 barrels that enhance its buoyancy and floatation.

Figure 6. Base of the building during construction *(Flotation platform)* (source; www.dezeen.com)

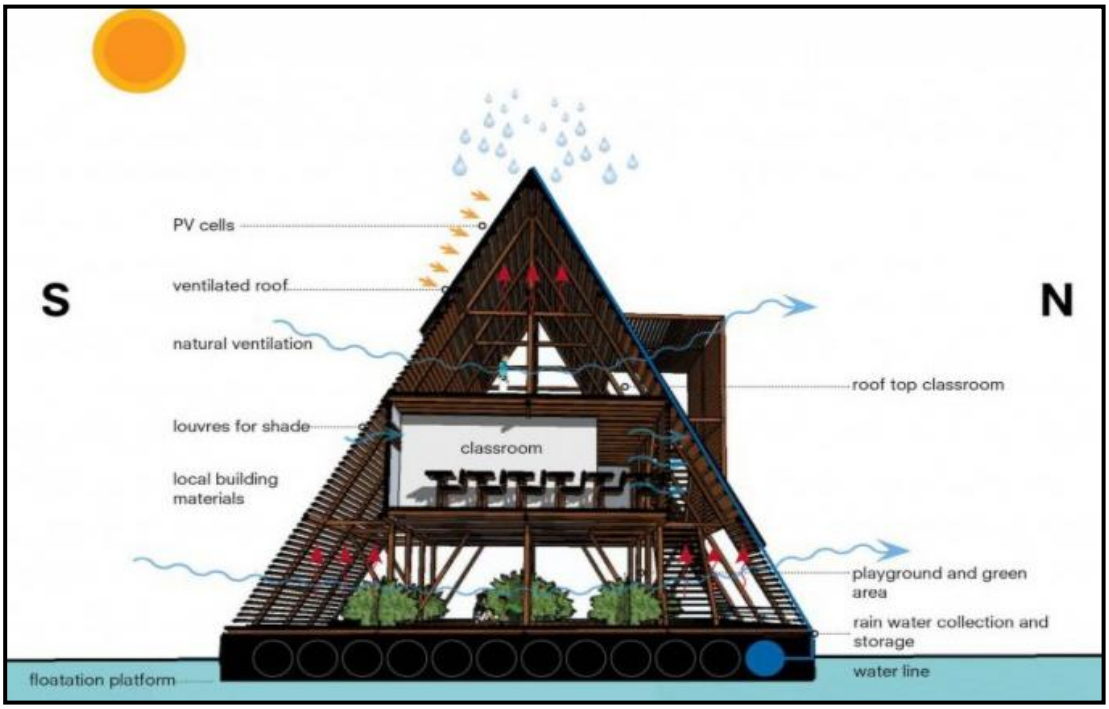

Figure 7. detailed cross section (source; www.dezeen.com)

The heating ventilation and air-conditioning system employed utilizes the passive means of cooling. It has open spaces on the first floor to facilitate air flow, a roof vent/ dormer window to maintain good indoor air quality, louvers for shade and a terrace roof for cross ventilation. In terms of building services, the simple yet innovative structure adheres to ideal standards of sustainable development with its inclusive technologies for renewable energy to supply constant power through solar panels, minimize waste, recycling of organic waste, harvesting of rainwater with sewage treatment as well as the promotion of low-carbon transport. This is well illustrated in the figure 7 below.

5. Results

The structural analysis of Makoko Floating School building reveals that the facility is inexpensive and elementary to assemble. The main aim of the school was to generate a new, sustainable and ecological building system for the teeming population of Africa's coastal regions but beyond this target its actualization emphasized the following.

- The design and construction of the floating school is much more diversified, humane, viable and cheaper because the middleman monopoly operated by governments and developers is cut off from the equation, with more cash invested directly and benefiting the community, rather than going into personal pockets. In order to construct the structure, local employees were hired with the idea that they could then go out and build their own homes with the techniques learnt while the school was being erected. Everyone in the community understands its value, not least because all of the materials used are ones they live with each day.
- The construction of a 'floating school' in Nigeria, in 2015, responded to the call of architecture connecting people and shooting into lime light the host community. The glimpse of the inspirational triangular timber structure – just three storeys elevated, yet capturing the eyes of all who travel across Africa's longest bridge was a ground-breaking developmental idea that made global news but a testimony to the inability and failure of the Nigerian State to meet even the most basic cultural and socio-economic needs of citizens over the years.
- In July 2012, Lagos State government under the governorship of Babatunde Fashola ordered that the stilts on the Iwaya/Makoko waterfront be demolished and dozens of stilts were demolished within 72 hours of notice to the residents. Nearly 3,000 people lost their homes to the partial demolition exercise. (Ogunlesi 2016) In the same vein Makoko was on the verge of demolition in early 2013. Since then, its floating school has earned a "pin" on Google maps, and on 20th April 2015, the Lagos State Ministry of Physical Planning and Urban Development announced that they are considering to incorporate the school's structure into a regeneration plan for the entire Makoko community. According to the architect (Kunle, 2013), "This is a rare and significant moment in history, where innovation is finally matched with an equally open-minded reconsideration of established policies …" It is an important signal for the mobilization of local and global interest that is critical for addressing the challenges and opportunities posed by rapid urbanization and climate change in developing African waterfront cities.
- Crafting a unique and an exception but innovative architecture grounded in place, memory and sustainability; it is seen as the Triumph of the human spirit to make something so good amidst so much poverty. This is in no way a glorification of poverty, but rather to demonstrate that there are

alternatives, and equally quality social developments, where the focus is not reaping return from land development, but putting distinctive community and culture square in the centre.

- There is no doubt that the school is an enclave but it is likely to contribute to the educational development of the slum district where teaching and learning are enhanced because the children have been confined to the environment they are used to (nothing is alien). Many may then argue that you do not need a school to receive education, but schools will undoubtedly add to the education received, so building one is always a laudable goal.
- Makoko was founded hundreds of years ago as a fishing village, but now climate change and rapid urbanization has threatened its way of life. Recall the main aim of the school was to generate a new, sustainable and ecological building system for the teeming population of Africa's coastal regions. It responded to the climatic and environmental constraint befalling them. Furthermore it transformed the negative image associated with waterfront communities when it solved an overpopulation crisis faced by a local community school.
- Architect Kunle's floating school drew attention to another waterfront community, 900km away in Port Harcourt. This community also struggled with forced removals and some clusters even managed to resist violent government opposition by organizing themselves into what is known as the 'Chicoco Mapping' - Chicoco being the black tidal swept mud where they are from. With this feat achieved in Makoko the community has hope that they can still live together.
- A more immediate impact of the new building is the powerful sense of ownership that Makoko's inhabitants derived from it – even before the doors to the school were opened. As the only public space in the area, it has become a vital meeting-point for the community where, when classes are out, market ladies park their boats and fishermen steal some shade to mend their nets. The floating building architecture's value goes beyond design and functionality because it is able to resonate deep within the hearts of people – people who, amidst a forced removal crisis, are able to read into this magnificent architectural structure a new message of hope (Riaan, 2014).
- The government was going to fill the shallow waters and build more of the stuff not out of place in Shanghai, London or Manhattan, much to the protest of the locals, which would destroy their way of life and community. Hence its erection flies against the practised norm of gentrification with asphalt plains, concrete boxes and cubic glass phallic symbols as the only solution to social development. The Floating School is considered a step in the right direction when it comes to addressing issues of global warming and the rising flood levels.
- According to Okeke *et*al., 2017 the traditional approach to design used to be that of man dominating his environment, therefore the floating school building has successfully utilized the concept of biomimicry (examining nature's solutions and applying them to building designs) to dominate its environment and address social and environmental problems with sustainable floatation principle.

6. Discussion

Architecture has always defined the human world from the simplest structure to the greatest monument, it is meant to put people before the pursuit of iconography, and therefore the development of life which has taken place likely in the environment of water needs to be accommodated in building design. There was and still is a fair affection of human beings for the water areas. Now it is possible- and in some cases, it even seems to be a necessity to return to the water places. In recent times the techniques are available to use the properties of

water in our favour (this means to use the possibilities of the mobility of architecture and energy resources of the surrounding water areas). Floating architecture has the following prospects;

- **Use of renewable energy resources**: The surrounding water can be used for heating and cooling through the year. For this, technique of evaporation, heat pipes or running water through the building envelopes by use of the buoyancy and minimized pumps are available.
- **A new feeling:** The direct contact with the natural environment of water is a base for an attractive property. Many people would like to spend their life in a floating house.
- **Additional construction ground:** Floating architecture will be a solution for the future lack of construction ground owing to the growing and expanding population of the world. In addition, in context with the rising sea level towns of floating houses could be an alternative construction ground.
- **New materials and innovative construction:** The construction and materials of floating architecture are subjected to the attacks of water and climate components such as wind waves, salts, solar radiation, and humidity etc. As to the sustainability new materials and composites of them with innovative properties are to be developed and tested.
- **Mobility:** One advantage of floating architecture over usual building is its mobility in view of changing positions or local places. Thanks to it, the owner can look for other places as desired and concerning his likings. Besides the subjective component the mobility is an advantages property with regard to the optimization of the solar energy inputs.

The advantages of a mobile building have a subjective side (everybody can choose a place according to his desires, ideas and technical references) and an objective side (by means of the possible position changes a maximum input of solar energy can be reached). A concentration of the infrastructure on one centralized location in a large district of several lakes connected through so-called channels reduces the costs of supply and waste disposal too.

6.1. Challenges

However, there are a lot of problems due to the special environment of water and its physical and chemical properties. Some of the problems of floating buildings and their floating bridges include:

- **Local climate:** The construction of floating building is subjected to stronger external loadings due to the increased attacks of wind, wind waves, driving rain and solar radiation.
- **Corrosion of materials:** The additional attacks by chemical and physical components of salts, ph-values, ions etc. and the special components of the local outdoor climate effect and intense corrosion of materials.

7. Recommendation

Environmentally-responsive architecture consists of building with design-in adaptability and responds to changes in climate, circumstances and needs. The benefits of this form of design are extensive and the building can remain in use for a long time. Therefore, the architecture of floating buildings is recommended to the costal lines and riverine areas of Bayelsa, Warri and Port Harcourt through government intervention because by

using local and recyclable building materials, buildings could be economically and ecologically more viable and can also be life-saving and offer instant solution of shelter in emergency situations.

8. Conclusion

Building on the water is not an easy feat, especially when a community is already struggling with overpopulation and gross space limitations. This innovation is truly outstanding, showcasing what a community can do to improve their plight when they work together. The floating school project highlights the fact that when one strives to understand the environmental setting and how it impacts in the society, you do not always have to destroy it to achieve what you want to build. Humans can adapt to the environment and still continue building dreams, without further adding harm to the environment. Indeed, through innovations such as the Makoko Floating School, it is not impossible to build sustainable and ecological urban water cultures, especially for Africa's coastal areas. Vernacular architecture has a lot to teach contemporary architects and engineers in terms of eco-friendly design approach. Education should therefore take the driving role in this evolution. Thus we need to move beyond the technical fixes perpetrated by present practice and begin to extend the architectural vocabulary towards articulating the temporality of natural and operational cycles in more diverse and creative way.

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