Flood Resilient Amphibious Housing: Barriers and Prospects

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Abstract

Being one of the most hazard-prone and disaster-stricken countries in the Asia-Pacific region, Bangladesh experiences severe havoc every year because of frequent natural disasters like cyclones, tropical storms, floods, droughts, earthquakes, river erosion, landslide, land subsidence, etc. Due to significant geographic position, abrupt changes in climatic conditions, and socio-economic diversity; the chronic occurrence of flood causes unbearable catastrophic consequences to human life, property, economy, health conditions, etc. Among the numerous advancements that are being intervened globally to mitigate the fragilities of the flood, various flood-resilient housing techniques are prominent and praiseworthy. Amphibious housing is a long-term flood-control technique that allows a regular building to float on the top of rising floodwater instead of being flooded. When an existing building is retrofitted with a buoyant base, it will rise as far as it needs to through storms while sitting on the ground in normal conditions. Amphibious housing has been proven effective in the Philippines, Vietnam, Cambodia, Netherlands, and so on. The prime feature of this study is to critically analyze the obstacles, along with the opportunities that will assist the housing resilience against floods, as well as compensate the damages during the floods by using the amphibious housing technique.

Keywords: *Flood Resilient Housing; Amphibious Housing; Flood Mitigation; Bangladesh.*

1. Introduction

One of the most important affords of the human race is the ability to battle and defend against flood vulnerability. The devastation caused by floods as a natural disaster has increased at an unprecedented pace globally. In South-East Asia, climate change and global warming are increasing the rate of flooding and sea-level rise (Mohamad et al., 2012). Flooding has become more vulnerable as a result of population growth and environmental degradation brought about by urbanization (Nekooie et al., 2017). The devastating Thailand flood of 2011 raised awareness of the need for village adaptation to brace for future floods (Saengpanya and Kintarak, 2019). Similarly, the 2013 Uttarakhand floods, 2017 China floods, 2018 Kerala floods, 2019 Pakistan floods and storms, 2020 Nepal floods were as severe and deadly to the affected regions. The situation in Bangladesh is no different because of its position on the Ganges Delta and the existence of distributaries that flow into the Bay of Bengal. Bangladesh is prone to flooding. Floods strike the country almost every year, wreaking havoc on lives, crops, infrastructure, and the economy (Bhattacharjee and Mukherjee, 2017). Every year, floods cover over 26,000 km^2 (10,000 square miles) of Bangladesh, killing over 5,000 people and destroying over seven million houses. As happened in 1998, the affected area during extreme floods can reach up to 75% of the region (Floods in Bangladesh - Wikipedia). Floods have a wide range of interconnected effects on people in flood-prone areas, including loss of livelihood, poor health, and mortality, lack of access to water and sanitation, food and nutrition, lack of safe places during floods, loss of education, infrastructure damage, and so on (Bhattacharjee and Mukherjee, 2017). As a result, the research inspires a need for a long-term, holistic approach that improves flood-specific resilience while still strengthening generalized resilience (e.g., livelihood and poverty-related challenges). This research examines a computational model for constructing a floating house in Bangladesh, which combines six groundbreaking techniques. It envisions floating houses that can be used on both land and water. This new housing concept is called amphibious houses. Amphibious housing is a constructive method for mitigating flooding that can be deployed without professional work with cheap materials and construction methods are easily replicable. It offers a secure and healthy atmosphere after flooding, allowing residents to return to their homes in situations that would otherwise force them to evacuate or put their livelihoods at risk. During rains, an amphibious house floats easily above water levels, with vertical steering posts restricting its lateral travel. When the floodwaters recede, the house returns to its original location on the property (Ropel-Morski et al., 2015).

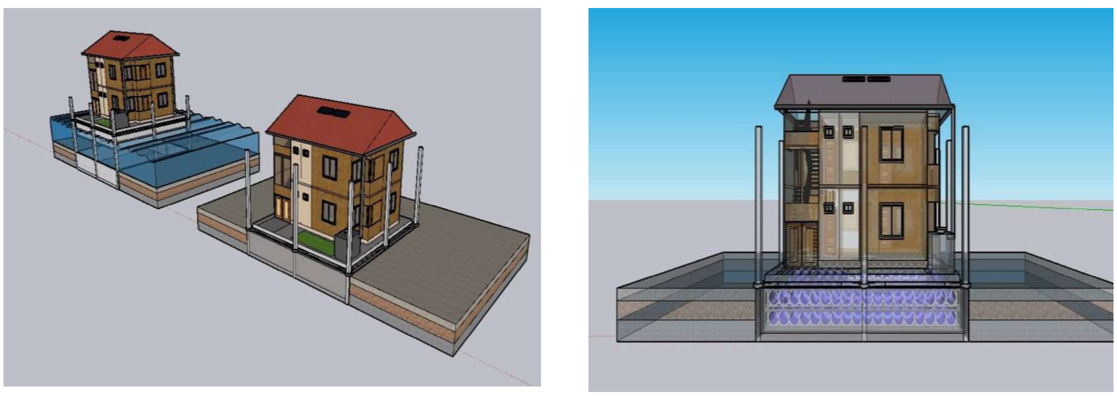

Figure 1: Illustration of a typical amphibious house model on flood water and land

A special form of the base known as the buoyant foundation is required for this type of floating house construction. A buoyant base is a form of amphibious foundation in which an existing structure is retrofitted to float as high as possible during floods while staying on the ground in normal conditions. The foundation is made up of three main parts: flotation blocks under the roof, vertical guideposts that keep the building from going in any direction other than just up and down, and a longitudinal subframe connecting both. Either self-sealing 'breakaway' ties or long, coiled 'umbilical' lines are used on utility lines. Elevated houses may be amphibiotic, but at a much lower cost (Buoyant Foundation Project). The house must be constructed with locally available materials under a very small budget. Specific objectives are given below (Bhattacharjee and Mukherjee, 2017):

- Mitigation of climate change-related losses and damage.
- The ability to cut, reuse, and recycle is built into the architecture of the floating house.
- A self-sufficient economic hub for maintaining livelihoods and raising revenue from food production.
- Assessing key aspects of mitigation and ensuring the protection and well-being of flood victims.

- Substitution of non-renewable energy sources for renewable energy.
- Environmental impacts and greenhouse gas (GHG) pollution can be reduced by using close to zero carbon emission building and passive methods.

2. Literature Review

Amphibious house is a new housing concept for us but it isn't that new at all, rather it is been widely used in some parts of the world. Elizabeth English has demonstrated the usage of buoyant foundation and retrofitting of the existing buildings as an amphibious house in New Orleans after the Hurricane Katrina catastrophe (English, 2009). In Malaysia, Mohammad Ali Nekooie has shown social recognition and understanding of floating urbanization and the implementation of amphibious houses (Mohamad et al., 2012). Another major advantage of this type of house construction is the need for less-skilled labor and the usage of cost-effective material and method of construction which has been deduced by Elizabeth English (Tramontini and English, 2015). In an amphibious housing group in Petoaha, a slum on Kendari's coastline, the theoretical and functional aspects of household sanitation technology, specifically the efficiency of a household septic tank equipped with an internal sand filter in reducing BOD_5 of domestic wastewater, have been used (Maheng et al., 2015). Another major issue is the land loss due to river erosion or the massive force of floodwater, which can be prevented by constructing this kind of amphibious structure and can be assessed by the Loss Avoidance Study showed by Elizabeth English (Sumanth and English, 2015). On the other hand, Shimantika Bhattacharjee has proposed a brilliant strategy for amphibious housing in Bangladesh's flood vulnerable areas including wind and flood-tolerant houses, vertical planting, harvesting of rainwater, livestock, and bio-digester, cage fishing, and the use of renewable energy (Bhattacharjee and Mukherjee, 2017). Bucket systems (pontoons) made of lightweight concrete with extended polystyrene blocks within have been described by Mohammad Ali Nekooie as an appropriate morphology for buoyant parts in amphibious houses (Nekooie et al., 2018). Although amphibious approaches won't solve all of the problems caused by climate change's increased impact on heritage architecture, they will provide communities with a resilient alternative for protecting their physical history and cultural heritage. Elizabeth English explains amphibious retrofit construction and how it can be used to save existing structures and neighborhoods (English et al., 2019). Retrofit the existing houses and proposal to build new amphibious houses in the coastline of Thailand to mitigate the flood damages has been discussed here (Saengpanya and Kintarak, 2019).

3. Case Studies

3.1 Maasbommel Waterdwellings, Netherlands

After three years of discussions with Rijkswaterstaat (the Dutch equivalent of the US Army Corps of Engineers), the construction firm Dura Vermeer was awarded a permit in 2005 for the construction of 34 amphibious houses in the Maasbommel River by Factor Architecten and Dura Vermeer. The houses are built on top of concrete basements, which also act as a buoyant floor, resulting in a watertight hollow space for resident occupancy and flotation. Steel rebar is used to reinforce the concrete basements that are constructed on-site. Two separate basements, each weighing 70 tons, are used to cement the concrete. Two fifteen-foot steel vertical guideposts are driven into the riverbanks using the concrete slab. Before the guideposts are set, the concrete frames are lifted into place and the timber houses are built on top of them.

Either pair is supported by concrete pilings or a concrete slab. The concrete piles act as a base for floating buildings, which are usually held in water all the year. To keep the houses as light as possible, the frame is built of wood. By strapping two steel plates to the corners of each concrete basement, steel bracing links the buildings. Thanks to the steel braces, all houses will rise and fall in lockstep with the river. The roof is constructed on the construction site and hoisted over the prefabricated timber frame foundation. When water levels are high, the houses can rise to 18 feet along with the two vertical guidance points. The vertical guideposts keep the houses from floating away at high tides by preventing lateral displacement caused by winds and waves. Flexible tubing is used to carry electrical wires, as well as water and sewer lines, inside the mooring posts (Anderson, 2014).

Figure 2: Amphibious housing (Maasbommel, the Netherlands) (*Source: Amphibious Housing in Maasbommel, the Netherlands — Climate-ADAPT*)

3.2 The LIFT House (Dhaka, Bangladesh)

In 2011, the LIFT House pilot project was constructed on the grounds of Bangladesh's Housing and Building Research Institute. As a part of Prithula Prosun's Master of Architecture thesis at the University of Waterloo, she proposed a novel approach to the housing system in developing regions; the house is self-supporting and free of the city's infrastructural constructs. To list a few utilities, occupants of the building have access to water storage, water treatment, and reuse, solar power, and composting toilets. The two residential units, which were planned as an experimental model, have different flotation systems. The base for the first unit is a rectangular reinforced concrete box that is open at the top and placed underground, similar to the Maasbommel amphibious dwellings (Boiten raadgevende ingenieurs bv, 2011). The buoyancy mechanism for the second device is unique; it's backed by a bamboo frame and filled with recapped, reused empty plastic water bottle packages. During a storm, 8,000 air-filled bottles dislodge enough water to lift the house and its inhabitants (Prosun, 2011).

Figure 3: LIFT House, Dhaka, Bangladesh (*Source: Prosun, 2011*)

4. Prospects of Amphibious Architecture and Construction

Floating and amphibious projects provide a viable option for improving existing floodplain ecosystems, revitalizing post-industrial waterscapes, and establishing vibrant waterfronts for developing countries like Bangladesh. Amphibious floating houses have a buoyancy function that makes them relatively resistant to natural disasters. Even though securing a calm water site is a precondition for the placement of an amphibious house, it is still necessary to design for dynamic forces. Amphibious houses are susceptible to environmental damage due to their movability, lifelong use, water cycle operation, precast, and standard construction. A new paradigm is needed in light of the resilient features of amphibious houses in the face of extreme climate change. If appropriate durable elements are added according to the conditions, amphibious/floatable houses may offer a possible new mode of resilient living (Moon, 2015).
Buildings of permanent static elevation elevate residents above street level, necessitating the use of several flights of stairs. In contrast, amphibious houses are just slightly raised off the ground to accommodate buoyancy components, allowing for greater accessibility. An amphibious system is more costly than conventional construction in new construction because it needs a more elaborate base structure. This could be 5-10% more costly as a percentage of overall construction costs, but it's a way to avoid the much higher costs of flood damage. In contrast to permanent static height, amphibious retrofitting saves a great deal of money. This is because permanent static elevation necessitates the removal of the entire base structure, whereas an amphibious retrofit simply adds mechanisms to provide vertical guidance to resist lateral forces and buoyancy to provide uplift to complement the foundation's ongoing gravity load-bearing function. According to a detailed cost comparison, amphibious retrofits cost one-third to half as much as permanent static elevation (English et al., 2016). When there is a shortage of building ground, this housing type could be a solution. In normal circumstances, the house stays on the field, but it will rise if flooding happens with its installed guidance posts. It also makes use of pipelines and electrical links operated by the city. Because of its mooring points, the house can rise and fall with limited lateral sway during floods. It can also promote high-density construction while leaving a small carbon footprint (Anderson, 2014).
Amphibious houses are easy to build and retrofit with so much less cost than traditional static elevated housing in flood-prone areas of Bangladesh. Here is given an overall cost of an amphibious house built as a prototype for a pilot project in Dhaka, Bangladesh by Prithula Prosun in 2011.

Table 1: LIFT House Pilot Project Construction Cost (*Source: Prosun, 2011*)

List of Works	Amount (BDT)
Bricks	90,000
Concrete	1,20,000
Bamboo	1,00,000
Used Steel Bars	50,000
Labor	1,50,000
Mechanical Work	85,000
Plumbing Work	5,000
Security	10,000
Total Cost of LIFT House with Two Units	**6,10,000**
Cost Per Unit	**3,05,000**

5. Barriers

Despite positive economic incentives, there are still many concerns and roadblocks to resolving. To overcome possible market entry obstacles, these issues must be resolved definitively (Penning-Rowsell, 2019). The growth of the industry requires the distribution of expertise unique to the design and development of amphibious and floating houses (Richard Coutts, Director, BACA Architects - Sleeper, 2020). Since most municipal officials have never seen or heard about the floating houses, they are unable to issue construction permits (Amphibious Housing in Maasbommel, the Netherlands — Climate-ADAPT, 2015). Only a few architects and developers can bid on floating construction projects because they have no prior experience working on the water. If the sector is not regulated by strict laws, regulations, and construction codes, floating and amphibious technologies may develop a negative public profile, causing prospective customers to be wary. Owing to a lack of rules and technical advice, contractors would be wary of potential liability claims. More research is required into the environmental effects of floating homes on the aquatic ecosystem, including the possible effects when floating structures decrease incoming sunlight significantly. If appropriate resilient features are implemented according to the conditions, limiting during the regulatory process, amphibious/floatable houses can offer a possibly different type of resilient dwelling (Foka, 2014). The majority of people are risk-averse when faced with a major life-changing decision, such as buying a house. Any people—families of young children or non-swimmers—will be put off by security worries, as well as concerns over mobility for the elderly or mentally ill and emergency medical facilities (Graaf, 2009).

6. Comparison with Traditional Facilities to Flood-prone Areas

The majority of an amphibious house takes place in a warehouse, as opposed to conventional housing architecture. Variables such as seasonal climates or environmental patterns, which often cause project delays, are not a consideration in amphibious accommodation. Furthermore, since all of these homes are mass-produced versions, whether for panelized structures or manufactured housing, a large portion, if not the entire finished unit, may have been designed well before it was purchased, allowing for immediate transportation and/or installation (Urkude et al., 2008). During floods and cyclones, the impacted populations of coastal regions are housed in cyclone shelters, which were built as elevated buildings in flood-prone areas of Bangladesh. Since the buildings are permanently built, these shelter homes are not safe or easily accessible for the aged or children. An amphibious home, in contrast to conventional housing schemes, is a game-changing option for providing anyone with security, convenience, and easy access.

7. Conclusion

The amphibious housing concept's methodology and collaborative nature make it ideal for scaling up and long-term sustainability, with a target population of 20,000 households and 1 million individuals. In comparison to conventional flood-tolerant facilities, this definition defines a revolutionary approach to adaptation. The resilience programs were chosen because they are directly relevant to local needs, are affordable, and can solve a variety of household challenges. While it is not a recent innovation, amphibious architecture in the last decade has become increasingly widespread. The use of buoyant foundations as a renovation or new construction could aid communities in the low ninth ward of New Orleans and in Bangladesh that are at high risk of constant flooding. Bangladesh is a country with a lot of rivers. It is vulnerable to floods due to its position on the Brahmaputra River Delta (also known as the Ganges Delta) and various distributaries that flow into the Bay of Bengal. As a result of its geographical location, Bangladesh is subjected to floods almost every year. Thousands of people lose their homes each year as a result of these floods. They not only lose their homes, but they also go without safe drinking water and food. The proposed amphibious house might be able to assist them in overcoming these long-standing issues. The house will provide them a haven as well as clean water and solar power. The proposed housing system will provide a long-term solution to those people who are chronically flooded for years.

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