# ENVISAGING THE SCOPE OF AMPHIBIOUS ARCHITECTURE IN BELOW SEA LEVEL REGIONS OF KUTTANAD

Nikhila Nelson

TKM College of Engineering

Kollam

niksnikhila7@gmail.com

***This research deals with the issue of frequent flooding in Kuttanad, which is lying below sea level. The people of Kuttanad are facing huge difficulties during floods especially the recurring damages happening to their properties and moving to some other safe places for shelter. Since Kuttanad is one of the most vulnerable area for flood, proper technologies should be implemented here to provide flood proof, safe and affordable structures for all residents of Kuttanad especially because majority of them are farmers and belong to Below Poverty Line.***

***This report will explore and documents the various ways of protecting and creating a sustainable living environment for residents in Kuttanad with the help of floating architecture. This dissertation will answer the questions like "How can a structure sits in ground can survive during floods?" In this dissertation, I focus on Amphibious architecture, which is the technique to provide houses for flood residents functioning both in land and water. Amphibious Architecture is cost effective and safe alternative for permanent static elevation with improved recovery from the disaster and it is achieved by buoyant foundations.***

***In order to ensure the well-being of the inhabitants, number of case studies are analyzed and interacted with the residents of Kuttanad itself, for the purpose of identifying key features that will facilitate the construction of amphibious houses in Kuttanad. This report is a response to design challenges raised by recent disastrous flood happened in 2018.***

Keywords- Floating architecture, Amphibious dwellings, Buoyant foundation, Flooding, Strategy

## I. INTRODUCTION

Kuttanad, which is known as the rice bowl of Kerala, is a region that has a deltaic trough-like formation which is the resultant of the convergence of four major rivers- the Meenachil, the Manimala, the Pampa and the Achenkovil, which drain into the Arabian Sea through the Vembanad Lake, is heavily prone

to flooding. There are huge losses for the people residing here every year who are almost 70% below poverty line. The scale of this disaster is very huge in Kuttanad which is having lots of paddy cultivation and the only place where farming is done below sea level. There are huge farms and since they are lying below sea level, the damages are caused easily on monsoons and everything is being damaged by flood which occur suddenly. With the occurring of flood, the residents are capable of adapting to the flood when the intensity is small, even though it is difficult. But with the increase in the intensity of flood, the residents are forced to move to other places or relief camps for shelter as their houses and neighborhood will be drowned. During the last recent floods of 2018, approximately 170,000 residents were moved to the relief camps. As the farms and houses drown completely in water during floods, the lives of people are much miserable and all activities will go down and freeze during this time and after the flood there are huge losses to their properties and is such a pathetic situation. The process and is continuing every year but still there are no effective schemes adopted to tackle this issue so far. A new residence for people in Kuttanad should be designed to withstand the rising water and frequent floods. Those residents should be safe, flood proof, eliminating the rebuild process after flood and thereby provide healthier and stable family. So it is high time to make a change in this scenario in this century of technologies and innovations. Floating architecture is one of the solution to this problem. Though it is not a new concept in the world of architecture, it is still not adopted in Kuttanad where it can have application and possibility.

Floating architecture is the field of architecture which deals with the architecture consisting of a floatation system at its base, to allow it to float on water. As a mean of flood resilience, amphibious architecture which is a part of floating architecture is to be adopted. Amphibious architecture adapts to dry and wet conditions without causing any damage during or after flood. Amphibious architecture refers to buildings that sit on dry land like ordinary buildings, except when there is a flood. During flood or if there is a rise in the water level, they are capable of rising and floating on the water surface until the floodwater recedes. The development of an amphibious community is a long time strategy that will minimize the potential risk of flooding in Kuttanad residences. A buoyancy system beneath the house displaces water to provide flotation as needed, and a vertical guidance system allows the rising

and falling house to return to exactly the same place upon descent. This is a proven strategy that has already been applied successfully in the Netherlands since 2005 and in rural Louisiana for about forty years. Amphibious construction is an adaptive flood risk reduction strategy that works in synchrony with a floodprone region's natural cycles of flooding, rather than attempting to obstruct them. The solution will also include waterproof material and protection of vital utilities, design of buoyant foundation, vertical guidance pole attached to the foundation, which provides resistance from lateral force caused by wind and water. Thus when this technology is found to be suitable for applying in regions of Kuttanad, then it will be of greater boon to Kuttanad when implemented.

## II. NEED OF THE STUDY

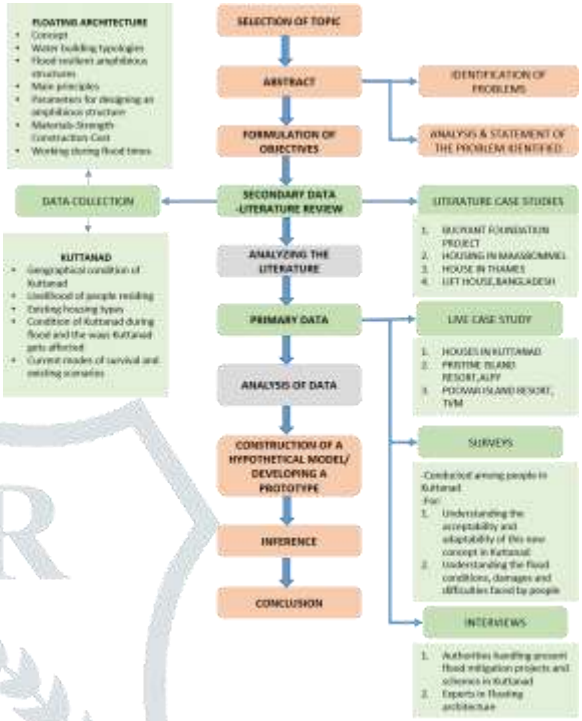
### *A. Scope*

The scope of this study is to realize the techniques adopted in construction of floating architecture and how it can be helpful in flood resiliency.

### *B. Limitations of the study*

The study part is limited to the study of amphibious architecture and its feasibility only in Kuttanad regions.

## III. METHODOLOGY




## IV. LITERATURE REVIEW

### *A. Floating Architecture*

i. Basic principles of floatation

A body floating or submerged in a fluid is buoyed (lifted) upward by a force equal to the weight of the fluid that would be the volume displaced by the fluid. This force is known as the buoyant force.

If the total weight of the entire home including the dead and live load of the house should be less than the volume of the water then the house can float.

ii. Water building typologies

- Terp dwelling

A terp is an artificial earthwork mound created to provide safe ground in the event of a rise in water levels.

- Static elevation

Method is elevating a house to a required or desired Base Flood Elevation (BFE).

- Pile dwelling

Pile dwellings are a type of housing built on top of concrete, steel or wooden poles and can be found in shallow water, coastal areas, or lakes where changes in the water level can be predicted

- House boats

Houseboats began with the conversion of ships and fishing vessels into livable environments. These types of houses resemble a land based property in its design and construction yet are buoyant enough to withstand the forces of water

- Amphibious dwellings

Amphibious housing is a dwelling type that sits on land but is capable of floating. During a sudden rise in water a house will be lifted by the water provided either by pontoons or a hollow basement in order to ensure it remains dry and will then return to the ground as the water recedes.

iii. Flood resilient amphibious construction

Amphibious architecture is a flood mitigation strategy that works in synchrony with a flood prone regions' natural cycles of flooding, rather than attempting to obstruct them. Although there are many types of strategies to defend against rising water levels, amphibious buildings are a proven flood protection strategy that gives a community defense against and improves its ability to recover from disaster. In environmentally sensitive locations, amphibious construction "lives with" the flooding, using the floodwater itself as the active agent to elevate a building. Rather than creating barriers, amphibious strategies accept the presence of floodwater but prevent it from causing significant damage to the building.

Experiment with amphibious houses is common in countries with flooding problem, though not in India. There is striking contrast between developed and developing countries for the choice of material and construction technology. Amphibious design also includes the concepts of land use planning, site selection, policy considerations and community resilience issues such as the place of amphibious buildings in multiple-lines-of-defense systems. Amphibious engineering addresses issues such as infrastructure, mechanical systems and utilities, system components and selection criteria, and codification and certification concerns.

However, amphibious architecture has much to offer to rural and low income populations in developing countries as well, either by inclusion in new low-cost housing projects or as a retrofit solution to increase resilience in flood-prone regions.

iv. Parameters for designing amphibious dwelling

- Capability of floating
- Foundation
- Float line
- Buoyant foundation height
- Structure type
- Road and parking conditions
- Utility access
- Fire safety
- Water maintenance

The basic equation for Archimedes force is as follows:

**U = G / (A x P)**

Where: U is the vertical drop below the water line (m) G is the dead load of the total building construction (kN) A is the area of the floating body ($m^2$) P is the density of water ($kN/m^3$)

v. Types of floating foundation

- EPS with concrete filling

Based on a core of polystyrene foam EPS and a concrete shell. This system gives the possibility to build on water and results in less draught so it can be used in more shallow waters. On top of these advantages the system is also unsinkable.

- Concrete hull

The hull is made from concrete which means there is no rusting

and condensation is minimal. These are hollow boxes of reinforced concrete, with enough buoyancy from the interior airspace to support the concrete as well as the structure.

- Pneumatic stabilizing platforms

A Pneumatic Stabilizing Platforms consists of multiple cylinders, made of steel or concrete or plastic. The air, which is enclosed in the cylinder by the deck on the top side and on bottom side by the water gives the platform its buoyancy.

- Plastic bottles

It utilizes plastic 2 ltr beverage bottles, which are extremely common, incredibly cheap and resistant to seawater. These bottles can be banded together into hexagonal grids of 7 bottles each. The grids are then stacked and layered to form a buoyant lattice. Some sort of rigid surface then needs to be placed on top of the floatation.

***B. Kuttanad***

i. General features of Kuttanad

Kuttanad which was known as the "Rice bowl of Kerala" in past. Kuttanad is the area with the lowest altitude in India, and one of the few places in the world where farming is carried out up to 1.2 to 3 m (4 to 10 ft) below sea level. The present Kuttanad region consists of 54 revenue villages, spread over 10 Taluks in the districts of Alappuzha, Kottayam and Pathanamthitta with an area of 1157 square kilometers. It is the largest wetland eco-system in the Indian west coast, is a marshy delta fed by four major rivers in its southern part viz, Pampa, Achenkovil, Manimala and Meenachil and receives inflows from two major rivers in its northern part ie, Muvattupuzha and Periyar rivers.

The climatic features of Kuttanad are typical of humid tropical features and it experiences fairly uniform temperature throughout the year ranging from 21 to 36 degree Celsius with 300 cm annual rainfall (83% from two monsoons- southwest and north-east) and 70-80%

humidity.Winds are in NW direction with a speed of 45-55 km/hr. Having a soil type which is mix of sand and clay. The level of salinity and acidity of water and soil here is very high.

ii. Condition of Kuttanad during floodtime

*Figure 1 Aerial view of flood affected Kuttanad in 2018 floods*

This section deals with problems of Kuttanad during flood times. The prime factor influencing the environment of Kuttanad is water. Management of water in different seasons holds the key to the environmental balance of Kuttanad. During the two monsoons the excess discharge of water from the four rivers to the Vembanad Lake causes floods in the entire Kuttanad region. However, as the level of sea is also high, the pressure of sea water does not allow automatic flow of flood water into the sea. Instead, the sea water may also enter Kuttanad adding to other flood hazards.

Flood causes untold misery to the life of the people. The floods cause breaching of bunds, which in turn, destroys the standing crops. When water level rises above the normal level, it causes great hardship to the people. During floods, the water transport will be suspended. Floods also cause heavy loss of property. The fruits and vegetables generally grown in the kitchen garden and home yard would be destroyed completely by floods. During floods, the main roads connecting upper Kuttanad with lower Kuttanad i.e., Thiruvalla with Thakazhy and Changanachery with Alappuzha will be partly under water, with bus services and postal services suspended for days. The occurrence of flood has become frequent in recent years. Several measures have been taken to prevent flooding of the region.

*Figure **Error! No text of specified style in document.** Flood affected house*

*Figure 3 People moving to safer places to escape from flood*

## V. CASESTUDIES

From the literature case studies, it was evident that amphibious architecture was successful in living with the flooding in different parts of the world.

| Sl.no | SHOTGUN HOUSE | HOUSING IN MAASBOMMEL | HOUSE IN THAMES | LIFT HOUSE |
|---|---|---|---|---|
| 1 | WATER TYPE | | | |
| | Salt | Fresh | Fresh | Salt |
| 2 | COST PER UNIT | | | |
| | 150,000 $ (20% more) | 310,000 $ (17 % less) | 840,000 $ (20% more) | 3700 $ |
| 3 | FOUNDATION | | | |
| | Sub-frame with EPS blocks | Concrete hull with rebar | Concrete hull | Ferro cement and water bottles |
| 4 | PLOT AREA (SqM) | | | |
| | 700 | 2865 | 2250 | 570 |
| 5 | MAXIMUM HEIGHT THAT CAN BE STRETCHED (ft) | | | |
| | 13 | 18 | 9 | 15 |
| 6 | ADVANTAGES | | | |
| | -Uses existing house -Maintains neighboring character -Retrofit is cheaper than static elevation | -Attached homes minimize sway from waves, vast interior space -Levee berm allows house to rest on land, minimizing corrosion | -Prefabricate -Better and vast interior space | -locally available materials are used -low cost structure |
| 7 | DISADVANTAGES | | | |
| | -Visible EPS foundation system | -Proximity to neighbors | -Height of house causes sway by waves | -Proximity to neighbors |

*Figure 4 Shotgun house*

*Figure 5 Maasbommel house*


*Figure 6 House in Thames*

*Figure 7 LIFT House, Bangladesh*

From live case studies of floating structures in Kerala – Emerald Pristine Island resort and Poovar Island resort, it is understood that the floating foundation commonly used in Kerala is concrete hull.

Live case study on Kuttanad was done to identify the existing housing conditions there. Some houses completely destroyed and damaged by the recent flood of 2018, some which are partly destroyed, some new stilt houses or static elevated houses, new stilt houses under construction and some other houses which are now raised by piles using hydraulic jacks ie, elevating the existing houses. Thus floating building typologies are now recently seen in the regions of Kuttanad.

*Figure 8 One storey elevated house*

*Figure 8 Pile dwelling*

*Figure 9 Pile dwelling under construction*

## VI. SURVEY

On conducting survey among the residents of Kuttanad, it was realized that most of the people are of the opinion that the lack of implementation of proper technologies are the reason for the worsening of damages caused by flooding. It was found that these people tend to stay in their house itself during flood times. Since Kuttanad is known for houseboats and boats, people are aware of floating architecture but most of them are not aware of amphibious architecture. When given an idea of amphibious architecture, majority of them were willing to adopt this technology as a means for resisting flood, but the cost is the major factor that prevent them from shifting to an amphibious community.

## VII. INFERENCE

- This research realizes the scope of floating architecture in regions of below sea level Kuttanad which is heavily prone to flooding

- Floating architecture can be a permanent flood mitigation strategy which can be used in Kuttanad and could resist the frequent flooding happening in this area.
- Amphibious dwellings can be more suitable and important in the Kuttanad, since it works in synchrony with the Kuttanad's natural cycles of flooding which is necessary for the farming rather than obstructing it.
- The scope of adopting amphibious structures which is a part of floating architecture as flood mitigation strategy in Kuttanad is high because now there already exists different types of floating architecture like static elevated structures, stilt or pile dwellings, houseboats.
- Amphibious structures have been successfully implemented in different parts of the world as a flood mitigation strategy and thus it can be implemented in Kuttanad also.
- When successfully implemented, Kuttanad could stand as a development model for the world.
- Floating modules needed for construction are costly and since 70% people residing in Kuttanad are below poverty line the cost for construction will be a great issue.it will be successful only if the government take essential initiatives regarding this and a mass production of this floating houses should be promoted, only thus the cost could be minimized.
- Kuttanad is known as the rice bowl of Kerala and also the only place where farming is done below sea level, so floating farms as part of floating architecture has a great scope and thus the contribution of Kuttanad in food production can be increased.
- Materials used in the construction should be

lightweight. The observed common material used is ferro-cement concrete hulls as the floatation base with lightweight sandwiched panels for walls.

- Corrosion resistant materials should be used since the flood water is mainly saltwater.

## VIII. CONCLUSION

Amphibious buildings are proven low impact flood protection strategy that gives a community enhanced flood resilience and improves its ability to recover from disaster. When flooding occurs the water dwelling vertically rises with the water levels to remain safely above water then settles back into places as the water recedes. Successful amphibious foundation system are functioning in the Netherland, New Orleans, Sausalito and Bangladesh, they can provide flood protection that is more reliable and more convenient than the permanent static elevations. The LIFT house in Bangladesh has proved low cost and sustainable building using locally available material and the house provides service system by not depending on government.

This dissertation has proved the stability and workability of existing amphibious residences and its importance in Kuttanad. With the reference of the different case studies and detailed description of the building material the construction technique of the amphibious structures, sustainable and low cost amphibious structure can be built in Kuttanad. Since flooding is a necessary process in Kuttanad for the farming to improve the fertility of soil, flooding can't be prevented but what needed is to live with the flood. For that amphibious architecture is the answer. This residents can also be like normal residents on land because all the same amenities as a building on land can be provided including heating, cooling and ventilation. The waterfront development can be developed by developing these amphibious dwellings. Quality of these structures is also maintained same as the building on the land.

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## X. REFERENCES

- Elizabeth English. Amphibious Foundations and the Buoyant Foundation Project: Innovative Strategies for Flood-Resilient Housing. Ontario: University of Waterloo School of Architecture. 2010. Print.
- BCDC Living with Water. San Francisco Bay Conservation and Development Commission, Oct. 2011. Web. 21 Jan. 2014
- Buoyant foundation project
- Fenuta, E. (2010) Amphibious architectures: The buoyant foundation project in Post-Katrina New Orleans
- Case study overview- Netherlands climate-adapt.eea.europa.eu/metadata/case-studies/amphibious-housing-in-maasbommel-the-netherlands/11310092.pdf
- Amphibious architecture_living with a rising bay digitalcommons.calpoly.edu/cgi/viewcontent.cgi?referer=&httpsredir=1&article=2318&context=theses
- A case study on Kuttanad shodhganga.inflibnet.ac.in/bitstream/10603/22785/11/11_chapter3.pdf
- Thriving with water: developments in North America-Academia.edu research paper
- SYMBIOSIS: Adaptations within Dutch Architecture and Urban Planning Practices in Response to a Changing Climate-pdf