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Integration of Flood-Resilient Amphibious Building Technology with the Sustainable Vernacular Architecture of Kerala – A Case of Thevarpathiyil Ancestral Home

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Abstract – *Amphibious buildings with buoyant foundations are flood-resilient building technology adopted worldwide. In order to design, develop and build such flood-resilient technology in India, there exists a need to understand the basic design concept, vernacular architectural principles and materials of the region in particular. 'Thevarpathiyil' home, situated at Bharananganam of Pala town in Kottayam district, is considered for this study as the simplest form in Vernacular architectural styles of Kerala. The study outlines the significant features of this 109-year-old home and compares it with the flood resilient building technology called amphibious houses built in Maasbommel, the Netherlands. Temporarily floating amphibious houses stay on land during the dry condition and only floats when it floods. The article summarizes the integration of resilient technology with the sustainability factor.*

***Key Words*: Amphibious houses, Flood resilience, Sustainability, Kerala, Vernacular Architecture, India**

1.INTRODUCTION

Resilience is the ability of a system to prepare for threats, reduce impacts, recover and adapt in response to disturbances. [1] Sustainability focuses on the preservation of traditional, social and environmental resources for future generations.[1] Considering the Triple Bottom Line concept; people, planet and profit, there must be an equilibrium between sustainability and resilience. While resilience is the immediate coping response of the system, sustainability ensures the system's survival in the long run.

The research aims to find the linkage between traditional vernacular architecture with contemporary flood-resilient technology. Will flood resilient amphibious houses integrate with the vernacular architecture of Kerala, benefit people and the environment under normal and extreme climatic conditions?

1.1 Kerala Floods

Kerala, a southern state of India, is densely populated with 860 persons per square kilometre. Kerala ranks first among Indian states on the Human Development Index (HDI). [1] Kerala is a narrow region sandwiched between the wavy seascape of the Arabian sea and hills with dense forests, Western Ghats. Therefore, the steep gradient is highly vulnerable to disasters and changing climatic conditions.

In August 2018, Kerala experienced severe floods and landslides affecting 5.4 million people, displaced 1.4 million people, and seized the lives of 433 people. [2] Over 17,000 homes were destroyed and 2.17 lakh, partially damaged. [2] A few regions like Kuttanadu and Munroethuruthu (Munroe Islands) in Kerala are periodically flooded. [Fig-1] The damages during the flooding are caused by the scouring of foundations, soil settlement, and water inundation. [2] The houses in low-lying areas with low plinth heights were damaged during the floods of 2018. Capillary action and water seepage weakened masonry walls built with cement blocks without plinth bands.

Fig -1: A periodically flooded house in Munroethuruthu or Munroe Islands in Kollam district of Kerala (Original photo shot by the first author)

The flood-damaged buildings with low plinth heights resulted in inundation for days. [2] The main reasons for housing collapses assessed are (i) high floodwater current, (ii) the inundation causing differential settlement of the foundations and (iii) flash floods, especially where the buildings are situated close to rivers and canals.

2. AMPHIBIOUS HOUSES

Flood resilient construction methods and Aquatecture developed and changed over the past few years. In Kerala, especially, people started to build Statically Elevated Houses (SEH) or houses on posts after the floods of 2018. Avoiding floodwaters by relocation is impractical in the long run. The

growing population and lack of livable areas in the state will make it more difficult for people to migrate to higher elevations in the near future. Raising buildings or SHE disintegrates the front porch culture or the 'verandah' culture with loss of neighborhood connection. Considering the practical implications of climbing in and out of such houses, every day, for the old and ill people makes it more socially distanced. The columns on which the house rests resist only the predicted water level and must be designed to resist water pressure, the weight of floodwater, scour and impact from floating debris. Dry proofing strategies to make the building resistant by keeping the water out (maximum 0.3 meters) and wet proofing strategies to make the building resilient by letting water inside the ground floor (water depths between 0.3 and 0.6 meters) are other flood adoption measures. [3] Permanently floating houses float on water and moves in a vertical direction with the floodwater.

Amphibious buildings fixed to a buoyant foundation rest on the ground and floats only when the floodwaters rise to make it a flood resilient structure with the ability to recover from a disaster. [4] The temporarily floating amphibious structure helps people to adapt from living on the ground to living on the water in time. [Fig-2] Buoyant foundations are made using concrete caissons, steel pontoons, polystyrene foam blocks or plastic barrels that have air-filled cavities and work according to Archimedes' principle. [5] The amphibious technology is practical to areas with (potentially) high inundation depths (max of 4.0 meters) by allowing the building to float when water levels rise above 0.6 meters. [3]

Fig -2: Amphibious house during dry condition on the banks of Maas River at Maasbommel, the Netherlands (Original photo shot by the second author)

The superstructure of such flood resilient buildings can be made using Glass Fibre Reinforced Gypsum Panels, Expanded Poly Styrene panels or Autoclaved Aerated Concrete (AAC) by analyzing the Kerala market. The cables, electricity, in this case, need to have long and flexible lines. As the house lifts, flexible utility lines extend from the ground and prevent cut off. It will safeguard the external supply while the residents get water and power, even when flooding happens. Renewable energy like solar energy can also be used for lights and to make it a self-sustaining structure.

2.1 Site Visit to Amphibious houses in Maasbommel, the Netherlands

In 2018, the authors conducted a site visit to the 32 amphibious houses and 14 permanently floating houses [Fig-3] situated on the banks of Maas River in the Municipality of West, Maas, n' Waal in the Netherlands. It contributed to the research and functional study of amphibious houses.

Fig -3: An amphibious house and a fully-floating house built near and in Maas River at Maasbommel, the Netherlands (Original photo shot by the first author)

The Maasbommel model of an amphibious house consists of a concrete-buoyant foundation with a lightweight superstructure. This pontoon floats when the Maas River overflows when the water depth is nearly 7 m NAP (Amsterdam Ordnance Datum). [6] The space inside the concrete-buoyant foundation is utilized as a living area. The two vertical guidance posts [Fig-4] help the structure stay in position with only freedom to move vertically up and down.

Fig -4: The guidance post between the two units of amphibious houses at Maasbommel, the Netherlands (Original photo shot by the second author)

Interviews with Mr. Adri van Ooijen, the Director of Watersport centrum of Maasbommel, and Mr. Jan Leder, owner of the house, resulted in the practical implications of the amphibious homes and the floatation experience during the 2011 flooding of Maas River.

3. VERNACULAR ARCHITECTURE OF KERALA

The traditional buildings built in Kerala are according to climatic conditions, wind direction and solar path. Generally, residential buildings follow traditional Kerala architecture based on 'Vaastu Saasthra' (the science of architecture and construction) for the building orientation, room measurements, cross-ventilation and 'Thatchu Saasthra' (the science of carpentry) for the structural work, especially woodwork.

The significant residential forms in Kerala includes 'Ekasala' – a single hall building type and 'Naalukettu' - a four-hall traditional house with an open courtyard at the centre. [7] Classical Indian architecture acknowledges a concentric arrangement of buildings and a generic spatial structure of the sala or hall. The 'Ekasala' is a single hall home, 'Dvisala' a two-hall home, 'Trisala' a three-hall home, and 'Chathusala' a four-hall house/courtyard house. [7]

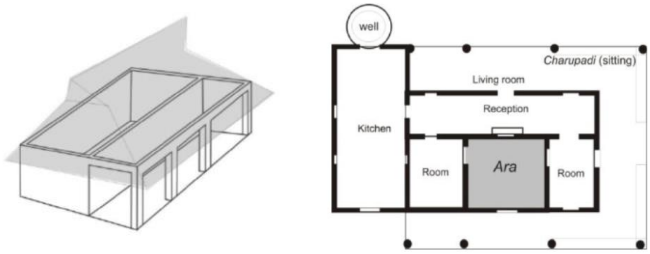

Fig -5: The core structure of 'Ekasala', vernacular style single hall building type and plan (not to scale) (Source: Widiastuti [7])

The 'Ettukettu' (eight-hall with two central courtyards) or 'Pathinarukettu' (sixteen-hall with four central courtyards) are the more elaborate forms of the same 'Naalukettu'. [7] Controlled temperature and humidity are ensured within this traditional architecture forms.

3.1 The case of Thevarpathiyil Ancestral Home

'Thevarpathiyil' home situates near the Meenachil River in Bharananganam village of Pala town of Kottayam district, Kerala. [Fig-6] The great grandmother of the first author lived for 103 years of age, of which about 93 years in the house. Also known as 'Tharavaadu', this ancestral home survived a minimum of 109 years by the year 2021.

The structure with a vernacular architectural style consists of a rectangular single-hall plan. According to the spatial and structural consideration, the form is 'Ekashala' with living rooms or 'muri' and one Granary ('ara') where rice grains, pepper, coffee beans etc. were stored. The structure is strengthened with wooden horizontal beams and circular columns on a raised floor. Thevarpathiyil, being an 'Ekashala' home, consists of -

1. a long verandah, which is the reception or open living space,
2. an inner core component, which is the living room
3. the main granary room, which is the 'ara', and underneath storage is called 'Nilavara'
4. and other supporting rooms for living and/or kitchen.

A secret 'ara' for the storage of owner's personal belongings make the home extraordinary.

Fig -6: Thevarpathiyil home with 'Ekasala' in the centre with extended portions, located at Bharananganam (Original photo shot by Yadu Jagadish, inhabitant)

The verandah protects the decorated wooden walls during the monsoon and summer seasons. [Fig-7] Therefore, the moisture absorption is less and hence, these wooden walls survive for over 109 years with minimal protective measures. The verandah and other floors of Thevarpathiyil 'Tharavadu' are of red oxide flooring.

Fig -7: Verandah / open living space of Thevarpathiyil home (Original photo shot by Yadu Jagadish, inhabitant)

The detailed woodwork is a key feature of such vernacular buildings in Kerala. Internal-external walls, doors, windows and roofs are built from 'Teak' (Tectona grandis) or 'Anjily' (Artocarpus hirsutuswood) with precisely carved out features. [Fig-8]

Considering Kerala's climatic conditions, hipped and gable roofs are the most common types with wooden truss frameworks and clay roofing tiles. For a narrow hall, the roof construction needs rafters, also known as 'Kazhukol' that are

stiffened by longitudinal beams and stiffeners. It is tied on top by a one ridge beam resting on a wall plate known as 'Uttaram' [7]]

Fig -8: A wooden door with detailed wooden carvings(left) and wooden walls and roof with the old 'ara' converted into a 'pooja' (religious) room of Thevarpathiyil home (right) (Original photos shot by the first author)

4. INTEGRATION OF VERNCULAR ARCHITECTURE WITH AMPHIBIOUS TECHNOLOGY

Generations after the construction of traditional houses, modern houses with flat roofs hit the market. The change negatively affected the structural integrity with changing humidity and temperature variations. The use of sloped roofs returned through aluminium sheets or asbestos with steel/GI trusswork over the existing flat roofs. A tropical state with monsoon seasons for half a year, the change was inevitable. Therefore, for a resilient home to be sustainable during wet and dry seasons. the use of sloped roofs is a vernacular architectural style

When amphibious houses in Maasbommel are compared with the architectural features of 'Thevarpathiyil' home, the buoyant foundation can be built similar to the raised floor of 'Ekasala'. The curved roof with slopes to the sides and the gable roof with slopes on all four sides point out the need for a slanting roof to allow easy water drainage during the rainy season. Light-weight panels are used to reduce the load from the superstructure onto the buoyant foundation. Considering vernacular panels or even the conventional ones in the market, a verandah or porch all around the house will reduce the moisture absorption of panels.

Structurally stable and climatically responsive architectural style contributed to the life span of 'Thevarpathiyil' ancestral home. The life span defines the sustainability of a house, ensuring the survival of the system, including its vernacular (traditional, social and environmental resources. The case study of Thevarpathiyil home is to analyze the minimal vernacular architectural features during the construction of a flood-resilient home in Kerala. The thermal performance of vernacular architecture with conventional building typology in terms of materials and techniques yields vital results regarding the environmental behaviour of a building system. The vernacular architecture of Kerala reflects the use of natural and passive thermal comfort methods for a warm-humid climate. The climate responsive features in Kerala, owing to the predominant seasons- rainy season and the non-rainy season will add to the sustainability of a resilient housing system. Excessive moisture present in the air during the rainy season and high temperature during the dry season are controlled with Kerala's vernacular architecture and Vaastushastra principles like building orientation according to the sun and wind, spatial arrangement and usage, with cross ventilation and pitched roof.

The verandah around the structure protects the walls even if they are wooden panels or modern commercial panels like Autoclaved Aerated Concrete (AAC) panel, V-Board panel or Glass Fibre Reinforced Gypsum (GFRG) panel. Proper planning and vernacular style of construction can contribute to the life span of the building. Open layout spaces are another factor that helps the structure to be environmentally friendly.

Amphibious houses help people to adapt without changing the usual lifestyle by preserving the vernacular architectural components. Therefore, we have developed the idea of an amphibious and floating building with a rectangular plan and four-sided verandah to safeguard the panel walls. [Fig-9]

Fig -8: A conceptual model of an amphibious house during floatation condition integrated with the vernacular architectural style.

A pitched roof with height and properly planned cross-ventilation will balance the inside temperature and outside temperature. The house will be resilient against floods and sustain climatic conditions using the vernacular materials and architecture of Kerala.

5. CONCLUSIONS

The Maasbommel-mode- amphibious house with a minimum of one 'Ekasala' will be built as a prototype structure in Kerala as a part of the research and development and to analyze the occupancy comfort. By uniting interdisciplinary researchers, practitioners, experts and entrepreneurs who work in the water and flood sector to assess and identify scalable solutions for accelerating the impact of such resilient technologies with the understanding

of vernacular principles will ensure sustainability. It is high time that we research, implement, learn and foster alliances to set projects in motion with innovative eco-technologies in the water sector by following the Triple Bottom Line concept; People, Planet and Profit.

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