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Review RTCET

Review of Amphibious Structures as A Flood Resilience Strategy Around the World

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Abstract

Over time, people have settled in communities that are fluvial flood zones and located at low elevations due to limited access to land, strong cultural ties that continue for generations, and economic factors that make relocation nearly impossible. "Our homes are stitched into the landscape," some say, "we have nowhere else to go." However, when the water continues to invade year after year, these populations face a perpetual threat to their survival and cultural heritage. As the seas advance, not only are the structures at risk, but so are fond memories, livelihood sources, and an important source of community belonging. Water intrusion is such a constant menace into people's lives, challenging their resolve to build, transform, and maintain their place in the face of this calamity. The concept of Amphibious structures has provided an innovative, adaptable and well approved solution for many of these areas since it allows structures to float temporarily with the fluctuations in water levels. In this context, it keeps the vibrancy and continuity of these communities amidst adverse conditions. This study will review the literature upon amphibious structures worldwide based on its design principles, construction techniques, materials, and adaptability to fluctuations in water levels while exploring the evolution of amphibious structures considering its historical roots, technological advancements, and modern implementations across various global contexts .Through a detailed review of various case studies , this research critiques the incorporation of amphibious design principles in different regions and assesses their effectiveness as a flood resilience strategy through secondary data analysis. Besides this study examines the viability of amphibious structures as a sustainable alternative to existing flood resilience methods. This paper aims to outline the crucial role that amphibious structures play in the development of flood resilience strategies globally and the vast potential these solutions hold for the future.

Keywords: Amphibious structures, buoyant foundation, flood resilience

INTRODUCTION

Amphibious structures are a relatively new architectural innovation specifically for the people who live in flood prone and low-lying regions with fluctuating water level. These buildings are researched and developed to rest on the ground in normal conditions but possess the ability to float with fluctuations in water levels. This peculiar hybrid form allows it to resonate according to changes in water levels, thus providing a pragmatic solution to the problem of recurring flooding [2,18].

The underlying premise of amphibious architecture is that most communities have built long histories of inhabiting flood-prone areas. This makes their relocation a near prospect because the residents are highly culturally attached to their land. Amphibious structures enable these communities to cling to their homes and cultural heritage while

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adjusting their life to water's realities [8].These buildings can float up with the floodwaters, minimizing damage and keeping essential services intact as they are built with buoyant foundation systems along with flexible utility connections [18],[9].

Historically, over the years, amphibious architecture has been motivated by conventional means of construction in places where water forms the primary element involved in everyday life. For example, at such places as Netherlands and Louisiana, with these ideas of amphibious design, houses have functioned for many years in a manner that they have mitigated the inundation due to seasonal changes(E. C. English et al., 2021; [21]. Due to improvement in materials and engineering, these buildings can more effectively work for many other settings [17]. Key components of amphibious construction are buoyant foundations, normally done using lighter substances like concrete or other materials that provide the necessary lift during floods. Guideposts are used to stabilize the structure, eventually leading the structure back to its original position after water recedes. This design solution protects physical structures and fosters community resilience through the ability to maintain residents in their own dwellings despite possible environmental disasters(E. C. English et al., 2021; [22].

Amphibious architecture is increasingly recognized as a viable sustainable option against traditional methods of flood mitigation. Accepting and integrating the natural periods of flooding rather than fighting them contributes to making such structures an effective solution for communities exposed to flooding dangers. The present development of innovative ways to coexist with water explains why amphibious structures constitute a significant strategy toward enhancing safety, preserving cultural identity, and building community resilience within flood-prone areas [8,11].

HISTORICAL BACKGROUND OF AMPHIBIOUS ARCHITECTURE

Amphibious architecture has its source in the centuries and lays hidden in the plasticity of adaptive reckonings of the first urban cultures exposed to flood-prone zones [26. Regions around the world from Asia, the Americas and Africa established form characteristics to accommodate seasonal and tidal variations in water level, allowing us to look back at an early awareness of resilience in buildings(E. C. English, 2016) . In Peru, the Uros who lived and worked on Lake Titicaca built floatable islands from multiple layers of totora reeds, buoyant structures that supported whole communities and provided the means of transport in the face of variable water levels [12]. Elevated stilt houses were the only residences in Southeast Asia, particularly in the Mekong Delta region of Cambodia and Vietnam [27].as well as in flood-prone regions across India, including Assam, Kerala, West Bengal, Bihar, and the northeastern states, with the purpose of safely living above inundating waters during monsoon season. Similarly, the indigenous people that reside in the Amazon Basin constructed floatable houses that would float up and down with the water level, using locally available, abundant materials such as balsa wood or other buoyant native hardwoods [23].

These ancient forms, although often of a basic design, represented complex environmental adaptation, and thus a relationship with water that was not adversarial but cooperative. For instance, in Thailand, the Ayutthaya Kingdom, established in 14th century, used floating markets and amphibious houses for urban design. The traditional point of view not only showed function improvement but also cultural adjustment to the natural ecosystem in which physical connections allowed for transportation and played a role in flood prevention[4]. African stilt villages, particularly the ones situated on the outskirts of Ganvie in Benin, which are informally called the "Venice of Africa", date back over 500 years, as they serve as a home for people fleeing river floodings, and historically serving as a shield against regional warfare (Ellis, n.d.). These past structures with amphibious nature show that the idea of living on water is not a new one; rather, it developed through indigenous knowledge and practical requirements that travelled through generations. The process of construction of these old floating or stilted houses has given an exceptional base to the contemporary version of amphibious architecture[3]. By studying these early forms, contemporary architects and engineers can draw lessons on material use, sustainability, and adaptability, using these historical practices to inform innovative designs suited to

today's climatic challenges. This long-standing water-centric bond in many cultures highlights that amphibious architecture is not merely a technical solution, but also a cultural ecological adaptation, that reflects an integrated strategy of harmonizing with the uncertainty of nature [11].

EARLY AND MID-20TH CENTURY DEVELOPMENTS

In the mid-20th century, amphibious architecture started to take shape as a solution to flood risks in densely populated areas prone to flooding[26]. The Netherlands was at the forefront of this research, creating flood-resilient structures based on its extensive history of water management. Following the devastating North Sea flood in 1953, the Dutch made significant investments in adaptive infrastructure, paving the way for future floating neighbourhoods(E. C. English, 2016). In the United States, Mies van der Rohe's elevated Farnsworth House, built in 1951, marked a turning point in flood resilience by incorporating elevation to reduce flood risk instead of relying solely on defensive barriers(Williams, 1945). Meanwhile, in Japan, architects began to explore buoyant designs that could endure both floods and earthquakes, further pushing the boundaries of adaptive architecture. These groundbreaking initiatives established the foundation for modern amphibious architecture, which combines engineering with architectural innovation to create sustainable solutions for flood resilience(Ibrahim Mohamad et al., 2012).

AMPHIBIOUS STRUCTURES AROUND THE WORLD CASE STUDY

Maasbommel Amphibious Homes, Netherlands (2005) [9]

- *Location:* Maasbommel, Gelderland Province, Netherlands
- *Architect:* Boiten Ingenieurs b.v.

The Maasbommel project exemplifies innovative amphibious architecture designed to address flood risks in low-lying areas along the Meuse River. This development features 46 homes, including 14 permanently floating structures and 32 amphibious houses that rest on concrete foundations during low water levels but can float when the river rises. Each home is constructed atop robust floating concrete hulls, which are prefabricated and weigh over 70 tons, ensuring stability and buoyancy during floods. The design incorporates a lightweight timber frame and an innovative flexible pipeline system that maintains utility connections despite water level fluctuations. The Maasbommel homes have successfully demonstrated their resilience during significant flooding events, providing a sustainable solution for residents in flood-prone regions while enhancing their quality of life fig 1[9] [11] [22].

Ban Tha Haek and Ban Khun Samut Chin, Thailand (2007)

- *Location*: Ban Khun Samut Chin, Samut Prakan Province, Thailand
- *Architect*: Chulalongkorn University

Figure 1. Amphibious houses, maasbommel.

The floating house project in Ban Khun Samut Chin utilizes an amphibious structural design that allows homes to adapt to changing water levels. Under normal conditions, houses remain grounded, but during floods, they rise and float on the water thanks to a buoyancy system consisting of expanded polystyrene (EPS) blocks integrated into the floor framework. Guidance poles anchor the houses in place, ensuring vertical movement only, which provides stability during flooding events. The primary goals of this project are to utilize locally available materials and straightforward construction methods that are economical and sustainable, emphasizing eco-friendliness and adaptability to local conditions. The design incorporates vertical guidance poles, waterproof substrate strapping, and reinforced concrete encasements around EPS blocks for flotation. Utility systems are designed with flexible lines that can disconnect and reconnect as needed during flooding. Initial studies indicated that floating buildings should mirror conventional structures while prioritizing occupant safety and structural strength. Load analysis confirmed sufficient buoyancy with EPS blocks designed to lift the structure during floods. The project represents an innovative response to the challenges faced by coastal communities in Thailand due to rising sea levels and coastal erosion Figure 2 [22].

LSU Prototype Amphibious House, Louisiana, Usa (2007)

- *Location*: Baton Rouge, Louisiana, USA
- *Architect*: Elizabeth English

The LSU Prototype Amphibious House represents an innovative solution to flood risks in Louisiana, developed in response to the vulnerabilities exposed by Hurricane Katrina. Established in 2006, the Buoyant Foundation Project aimed to create flood-resistant housing that preserves the character of traditional shotgun houses while enhancing resilience against future disasters. The design allows the house to float during floods while remaining anchored under normal conditions, utilizing a buoyant foundation system with EPS (expanded polystyrene) blocks for flotation and a vertical guidance system to ensure stability during flooding events. Measuring 13 feet by 24 feet, the prototype was constructed and tested in 2007, simulating flood conditions to assess its effectiveness in floating and returning to its original position after water recedes. The testing confirmed that the design could mitigate flood damage while maintaining stability and connection to the environment. With a buoyancy system costing approximately $5,000, significantly less than traditional elevation methods, this project exemplifies a forward-thinking architectural response to flooding challenges in Louisiana. By integrating buoyant foundations with traditional designs, it offers immediate flood protection and promotes long-term resilience for communities vulnerable to climate change impacts Figure 3([8] Fenuta, n.d.)

Float House, New Orleans, Usa (2009)

- *Location*: Lower Ninth Ward, New Orleans, Louisiana, USA
- *Architect*: Thom Mayne and Morphosis Architects

The FLOAT House is an innovative prototype designed to meet the needs of families in New Orleans' Lower Ninth Ward, developed by architect Thom Mayne and a team of graduate students from UCLA's Department of Architecture and Urban Design. This first floating house permitted in the United States reflects the vibrant culture of New Orleans while maintaining the vernacular design of traditional shotgun houses. The FLOAT House sits atop a prefabricated raised base made of expanded polystyrene foam coated in glass fiber-reinforced concrete, which integrates all mechanical, electrical, plumbing, and sustainable systems. This 4-foot base allows the house to rise up to 12 feet during severe flooding while preserving the community's vital porch culture for accessibility. Connected to vertical guideposts anchored by concrete pile caps, the FLOAT House is designed to float securely during floods. The project emphasizes affordability and sustainability, featuring solar power generation, rainwater collection systems, and high-efficiency plumbing and appliances aimed at achieving a LEED Platinum Rating. By combining modern mass production with traditional construction methods, the FLOAT House serves as a scalable model for affordable housing adaptable to flood zones worldwide figure 4[16].

Figure 2. Floating house project in Ban Khun Samut Chin.

Figure 3. LSU Prototype amphibious house.

Figure 4. FLOAT House.

Amphibious Houses in Ise City, Japan (2011)

- *Location*: Ise City, Mie Prefecture, Japan
- *Architect*: ICHIJYO Co., Ltd.

The amphibious houses in Ise City, developed by ICHIJYO Co., Ltd., represent a comprehensive approach to flood resilience by addressing four main vulnerabilities: inundation, backflow, submersion, and buoyancy. To prevent inundation, the design incorporates an underfloor ventilation port with a float valve that seals during rising water and reopens as it recedes, along with waterproof exterior wall sheeting and watertight patio doors. For backflow prevention, specialized valves block sewage from entering the home during floods. Critical systems remain operational through redesigned flood-resilient pumps and elevated external equipment. To counteract buoyancy during extreme flooding, the houses utilize a water ballast method that allows water into the underfloor space for added weight, and a floating and mooring system that anchors the home while enabling it to rise with floodwaters. This integrated flood-protection strategy enhances safety and stability in high-risk flood areas, showcasing innovative architectural solutions tailored to the unique challenges of climate change and flooding in Japan Figure 5[14].

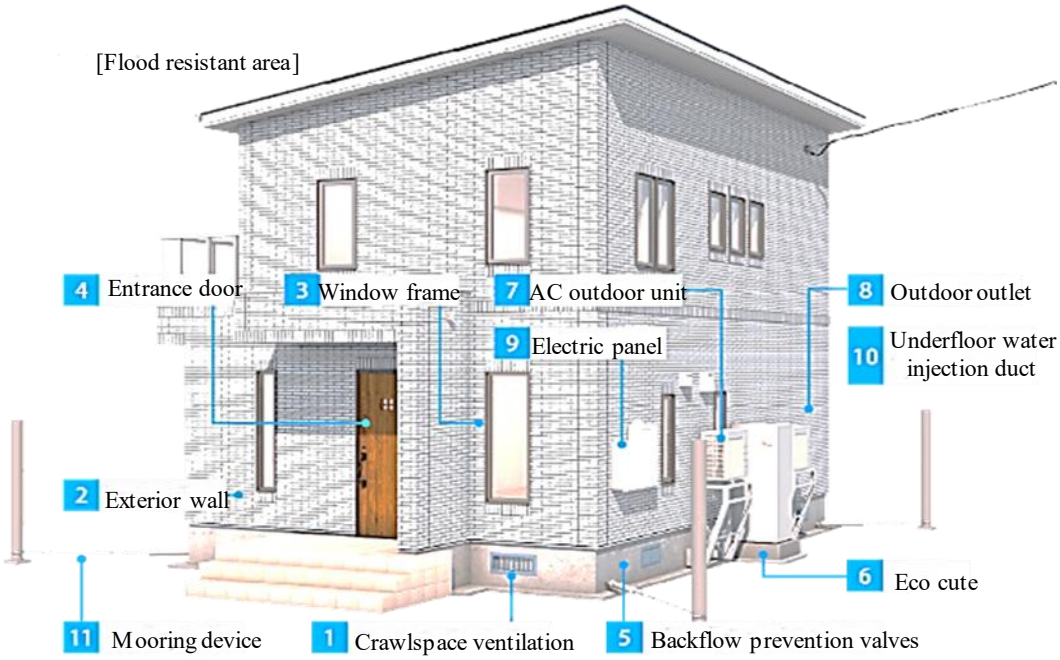

Figure 5. Integrated flood-protection systems in the amphibious houses in Ise City.

Buoyant Foundation Project (2013)

- *Location*: Various locations, including New Orleans, Louisiana, USA; Waterloo, Ontario, Canada; and Mekong River Delta, Vietnam
- *Architect*: Elizabeth English and the Buoyant Foundation Project team

The Buoyant Foundation Project (BFP) addresses the challenges of frequent flooding in low-lying areas by developing adaptable, cost-effective amphibious retrofits for homes. Founded by architect Elizabeth English in 2006, the project equips existing structures with buoyant foundations that allow them to rise with floodwaters and safely return to ground level as waters recede. Utilizing expanded polystyrene (EPS) foam blocks for buoyancy and telescoping steel guidance posts to prevent lateral drift, the BFP ensures homes remain stable during floods. This low-cost, passive solution minimizes disruption, enabling communities to maintain their traditional lifestyles without relying solely on large-scale flood defence systems. Notable projects include an amphibious pavilion in Waterloo, Ontario, designed to demonstrate the concept of amphibious construction for Indigenous communities and retrofitted houses in Vietnam's Mekong River Delta to enhance flood resilience against increasing climate threats. The BFP empowers residents to protect their homes and possessions, offering a resilient alternative to costly elevation or relocation in the face of escalating flood risks Figure6.

Figure 6. 1.Amphibiation in the Mekong river delta 2.NRC research pavilion, waterloo, ontario.

Formosa, UK (2014)

- *Location*: Marlow, Buckinghamshire, UK
- *Architect*: Baca Architects

The Amphibious House, designed by Baca Architects, is the UK's first amphibious residence, located on the banks of the River Thames in Marlow. This innovative structure addresses the challenges of flooding in Flood Zone 3b while blending adaptive functionality with aesthetic design. The house features a unique "intuitive landscape" that acts as a visual early-warning system for flooding; a terraced garden floods sequentially to alert residents of rising water levels. Anchored by four vertical steel posts known as "dolphins," the house can rise up to 2.5 meters above flood levels while preventing lateral drift. Operating solely on electricity, the house uses flexible "elephant cabling" for essential utilities, ensuring functionality during floods. The project required extensive negotiations with regulatory bodies to set a precedent for future designs and represents a significant advancement in sustainable, flood-adaptive housing. By integrating resilient features with thoughtful landscape design, the Amphibious House serves as a model for future developments in flood-prone areas Figure 7.

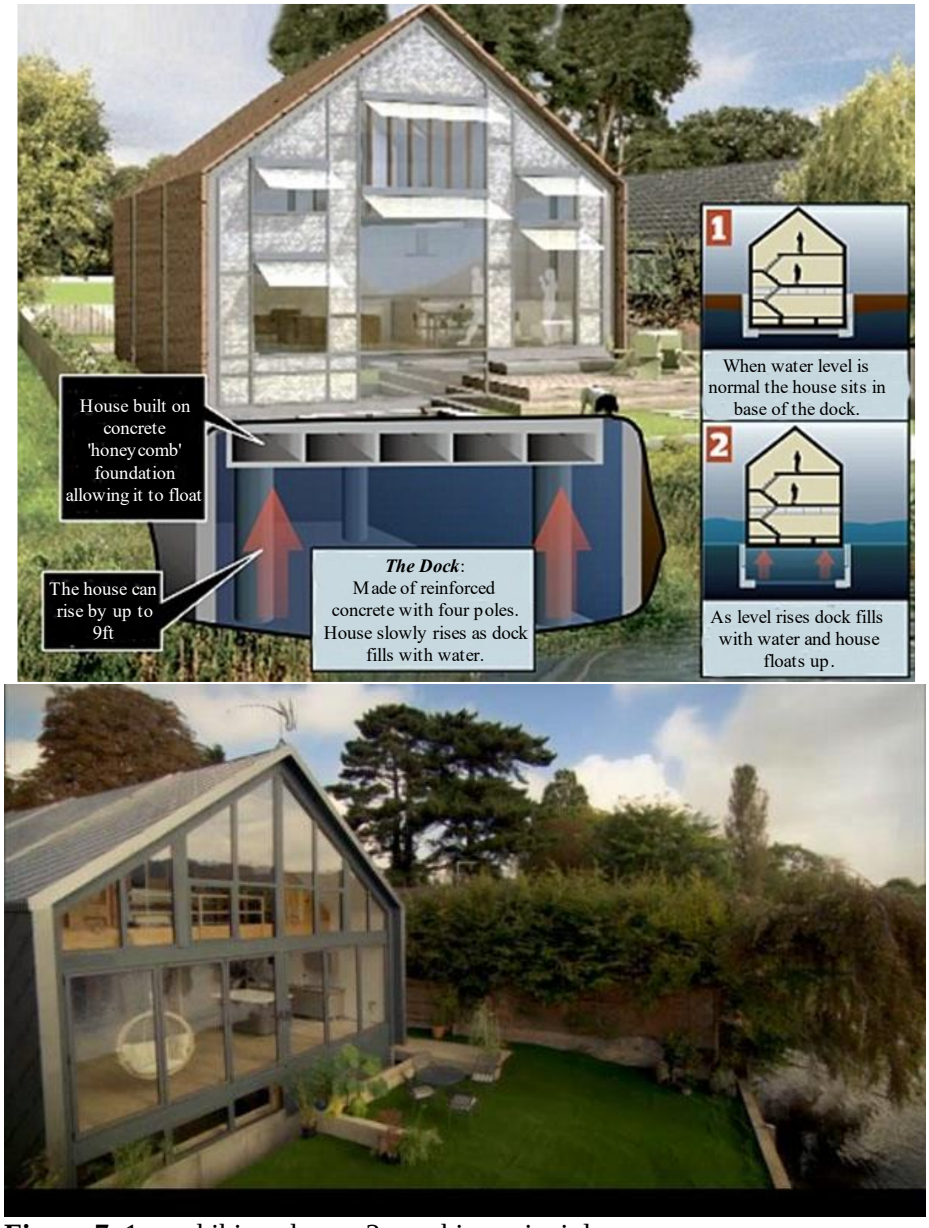

Figure 7. 1.amphibious house 2. working principle.

Pinaymootang First Nation Amphibious Houses, Manitoba, Canada (2014)

- *Location*: Pinaymootang First Nation, Manitoba, Canada
- *Architect*: Elizabeth English and the Buoyant Foundation Project team

The Pinaymootang First Nation Amphibious Houses project aims to address the significant flooding challenges faced by this Indigenous community in Manitoba. Developed as part of a pilot program, the initiative focuses on creating affordable and culturally sensitive amphibious housing retrofits for existing prefabricated homes. The project involves moving these homes from a decommissioned military base to flood-prone sites on the reserve and equipping them with buoyant foundations. Community members are actively involved in the construction process, gaining hands-on experience in implementing amphibious retrofits. The design incorporates buoyancy blocks that allow homes to rise with floodwaters while maintaining stability and preventing lateral drift. This innovative approach not only enhances flood resilience but also empowers residents to replicate the retrofit process in their own homes, fostering self-sufficiency and knowledge sharing among Indigenous populations at risk of flooding. By integrating community engagement with practical solutions, this project serves as a model for sustainable housing adaptations in vulnerable regions Figure 8[24].

Water studio Floating Mosque, Dubai, Uae (2014)

- *Location*: Dubai, United Arab Emirates
- *Architect*: Waterstudio.nl

The Water studio Floating Mosque, designed by Waterstudio.nl, is an innovative architectural project that combines modern design with traditional Islamic functionality. Completed in 2015, this mosque features a daring and contemporary aesthetic characterized by giant funnel-shaped transparent columns that not only support the roof but also allow filtered light to illuminate the interior space. Situated on water, the mosque exemplifies a unique approach to religious architecture in a flood-prone region, providing a serene and reflective environment for worship. The project was commissioned by Dutch Docklands International and serves as a symbol of resilience and adaptability in the face of rising sea levels and climate change challenges. By integrating sustainable design principles with cultural significance, the Floating Mosque sets a precedent for future aquatic architecture in urban coastal settings Figure 9.

Figure 8. Pinaymootang first nation amphibious house.

Figure 9. Water studio floating mosque.

Float Base, Hamburg, Germany (2015)

- *Location*: Hamburg, Germany
- *Architect*: Waterstudio.nl

The FLOAT Base in Hamburg, designed by Waterstudio.nl, is an innovative amphibious structure that addresses the challenges of rising water levels and flooding in urban areas. Completed in 2015, this project features a buoyant foundation that allows the building to float on the Elbe River during high water events while remaining anchored to the ground under normal conditions. The design incorporates a series of floating platforms that provide flexible use of space for various functions, including recreational and community activities. The structure is equipped with sustainable systems such as rainwater collection and solar energy generation, enhancing its resilience and minimizing environmental impact. By integrating modern architectural techniques with adaptive flood management strategies, the FLOAT Base serves as a pioneering model for future developments in flood-prone urban settings, promoting a harmonious relationship between architecture and water. Figure 10

Makoko Floating School, Lagos, Nigeria (2017)

- *Location*: Makoko, Lagos, Nigeria
- *Architect*: Kunlé Adeyemi and NLÉ

The Makoko Floating School, designed by architect Kunlé Adeyemi and his firm NLÉ, was completed in 2013 as a pioneering educational facility addressing the needs of Lagos' waterfront communities. This innovative structure serves as a prototype for floating buildings in the densely populated Makoko area, where land is scarce and flooding is a recurring challenge. Utilizing local materials such as bamboo and reclaimed wood, the school reflects the community's craftsmanship and sustainable practices. The A-frame design features classrooms on the upper level, surrounded by public green spaces and a playground below, promoting a vibrant learning environment. Equipped with solar power and rainwater collection systems, the floating school exemplifies sustainable architecture while providing essential educational services to local residents. Despite its success, concerns about environmental impacts on aquatic ecosystems arose, highlighting the need for careful consideration in future floating structures. The Makoko Floating School has been recognized as a milestone in community-focused design and continues to inspire further developments in floating architecture worldwide Figure 11[15].

Figure10. FLOAT base in hamburg.

Figure11. Makoko floating school.

Lift House, Dhaka, Bangladesh (2018)

- *Location*: Dhaka, Bangladesh
- *Architect*: Prithula Prosun

The LIFT House, designed by architect Prithula Prosun, is a pioneering amphibious housing solution developed between 2009 and 2010 for low-income communities in flood-prone Dhaka. As the first engineered amphibious housing project outside the Netherlands and the US, it addresses the challenges posed by seasonal flooding in low-lying areas. The structure employs two types of buoyant foundations: a hollow ferrocement foundation and a bamboo frame filled with recycled plastic bottles, allowing the house to float as water levels rise. The dwelling features a central brick service spine that houses essential systems such as rainwater cisterns and a vertical guidance system to stabilize the floating units. Rainwater is collected from a catchment area, with a capacity of up to 100,000 liters annually, while an on-site composting system provides sanitation solutions. Electricity is generated through solar panels, ensuring self-sufficiency without reliance on city infrastructure. The LIFT House exemplifies an affordable, resilient model for flood-adaptive housing, utilizing local materials and labor to support sustainable living in vulnerable urban areas Figure 12[22].

Figure12. LIFT house.

Figure13. Schoonschip floating village.

Schoonschip Floating Village, Amsterdam (2020)

- *Location*: Buiksloterham, Amsterdam, Netherlands
- *Architect*: Space&Matter and various architects

Schoonschip is a pioneering floating village in Amsterdam, completed in 2020, that exemplifies sustainable urban living by integrating ecological and social sustainability within an innovative architectural framework. Located in the Buiksloterham area of Amsterdam-Noord, the village consists of 46 floating homes across 30 water plots on the Johan van Hasselt Canal. Designed by various architects, the homes feature diverse architectural aesthetics while prioritizing sustainability. The community houses over 100 residents and includes semidetached homes known as "kangaroo houses," enhancing accessibility and affordability. Schoonschip is energy self-sufficient, equipped with over 500 solar panels and 30 heat pumps, allowing residents to trade energy among themselves through a decentralized energy grid. Advanced wastewater recycling technologies recover energy and nutrients for reuse, while composting and shared resources promote waste reduction. Developed through active resident participation, Schoonschip fosters a sense of ownership and responsibility, featuring communal spaces that encourage interaction and collaboration. This floating village serves as a model for future urban developments in response to climate change and urbanization, demonstrating how innovative design can create resilient communities on water Figure 13 (Mendelson, 2021; Schoonschip, Amsterdam, the Netherlands - Bartels &Amp; Vedder, 2020).

Amphinest In Kerala, India (2021)

- Location: Kuravilangad, Kottayam District, Kerala, India
- Architect: Nanma Gireesh and Ben K. George, NestAbide

The Amphi Nest is a groundbreaking prototype amphibious structure developed by Nanma Gireesh and Ben K. George of the startup NestAbide, aimed at providing resilient housing solutions in flood-prone Kerala. Completed in 2021, this innovative design arose in response to the catastrophic floods that devastated the region in 2018, prompting a need for affordable and adaptable housing. The Amphi Nest features a concrete buoyant foundation that allows the structure to float during floods while remaining stable on land under normal conditions. Measuring 200 square feet and constructed at a cost of approximately ₹3 lakh , the prototype serves both as a practical solution and an educational tool to raise awareness about amphibious living. The design includes a wet dock to simulate flood conditions and demonstrate its functionality. Since its inauguration by Kerala's Minister for Agriculture, the Amphi Nest has gained significant media attention, including coverage on BBC's World Podcast. Following its success, NestAbide is pursuing additional projects funded by the Kerala Development Innovation and Strategic Council (KDISC) to provide homes for low-income families in flood-prone areas. The initiative emphasizes community involvement in the design process, ensuring that solutions align with local needs while promoting sustainable living practices adaptable to changing environmental conditions Figure 14 and table 1[11].

Figure14. Amphi Nest prototype.

Table 1. [Review of amphibious structures around the world].

Project Name	**Year**	**Location**	**Architect**	**Type of Structure**	**Buoyancy Mechanism**	**Foundation System**	**Design Principles**	**Materials**	**Strategies and Adaptation to Regional Conditions**	**Efficiency Evaluation**
Maasbommel Amphibious Homes	2005	Maasbommel, Netherlands	Boiten Ingenieurs b.v.	Amphibious / Floating Homes	Buoyant concrete hull	Flexible concrete dock system	Flexibility and resilience to flood risks	Concrete hulls, lightweight timber frames, flexible	Utilizes prefabricated heavy concrete hulls for stable buoyancy;	Highly resilient for periodic river
Ban Tha Haek and Ban Khun Samut Chin	2007	Samut Prakan Province, Thailand	Chulalongkorn University	Amphibious Houses	EPS blocks	Reinforced concrete stilts	Local material use, eco-friendliness	EPS blocks, reinforced concrete	EPS block buoyancy provides affordable flood	Effectively adapts to frequent
LSU Prototype Amphibious House	2007	Baton Rouge, Louisiana, USA	Elizabeth English	Prototype Amphibious House	EPS blocks	Timber framing	Retaining traditional housing forms, low-	EPS blocks, timber framing	Telescoping steel posts stabilize during flooding;	Reliable post-flood ground
FLOAT House	2009	New Orleans, USA	Thom Mayne, Morphosis Architects	Floating House	EPS foam with glass fiber-reinforced	Raised platform on flexible	Affordability, sustainability and	EPS foam with glass fiber-reinforced	Guideposts for structure stability, solar power, rainwater	Efficient in handling New
Amphibious Houses in Ise City	2011	Ise City, Japan	ICHIJYO Co., Ltd.	Amphibious Houses	Water ballast system	Waterproof exterior	Integrated flood protection, stability	Waterproof exterior, water ballast	Backflow prevention systems and float valves prevent	Strong flood resilience, adaptable
Buoyant Foundation Project	2013	Various	Elizabeth English and BFP team	Amphibious Retrofit	EPS foam blocks	Telescoping steel posts	Passive adaptability, preservation of	EPS foam blocks, telescoping steel posts	Retrofits homes with telescoping guideposts for stability,	Cost-effective and flexible,
Formosa Amphibious House	2014	Marlow, UK	Baca Architects	Amphibious House	Steel frame foundation	Concrete foundation with steel	Early flood-warning through landscape	Steel posts, concrete foundations, flexible	Flexible utility systems and terraced landscaping	High efficiency for UK' s
Pinaymootang First Nation Houses	2014	Manitoba, Canada	Elizabeth English and BFP team	Amphibious Houses	EPS blocks	Timber and steel guidance	Community engagement, affordability	EPS blocks, timber, steel	Involves community in flood-resilient constructio	Strong seasonal flood
Waterstudio Floating Mosque	2014	Dubai, UAE	Waterstudio .nl	Floating Mosque	Floating pontoons	Transparent columns	Integration of tradition and modern design	Transparent GlassReinforced ConcreteSte	Light-filtering columns, adaptable floating	Highly symbolic, suited to

FLOAT Base	Makoko Floating School	LIFT House	Schoonschip Floating Village	Amphibious Prototype	Floating platforms	Floating platforms	Flexibility in urban space use, sustainabi	Floating platforms, solar panels,	Solar energy, rainwater collection, adaptable	Highly efficient in dense
2015	2017	2018	2020	2021	Hamburg, Germany	Lagos, Nigeria	Dhaka, Bangladesh	Amsterdam, Netherlands	Kuravilangad, Kerala, India	Waterstudio.nl	Kunlé Adeyemi, NLÉ	Prithula Prosun	Space&Matter, various architects	Nanma Gireesh, Ben K. George	Amphibious Housing	Floating Village	Low-Income Amphibious House	Modular floating platforms	Buoyant foundation	Precast concrete pontoons	Concrete foundation	Amphibious Prototype	Community awareness, affordability	Energy self-sufficiency, waste reduction	Concrete buoyant foundation	Solar panels, composting systems	Community engagement, wet dock flood simulation,	Decentralized energy, wastewater recycling, composting	culturally relevant, resilient,	High efficiency towards	Practical for frequent flooding;	Efficient for community use; self-	Highly efficient in dense
					Amphibious Platform	Floating platforms	Floating platforms																											

EMERGING AND ONGOING PROJECTS

Floating City Project ,Busan, South Korea (Ongoing)

The Floating City Project in Busan seeks to establish a sustainable urban habitat designed to withstand rising sea levels and evolving climate conditions. This forward-looking project envisions a floating city that integrates residential, commercial, and recreational zones, all positioned on the water. With a focus on ecological resilience, the city incorporates renewable energy and sophisticated waste management, offering a blueprint for future coastal urban developments aimed at supporting communities in flood-prone areas.

Amphibious Housing in Port Maria and Bliss Pastures, Jamaica (Ongoing)

In Jamaica, the Amphibious Housing initiative in Port Maria and Bliss Pastures provides adaptive housing solutions for flood-vulnerable communities. These amphibious homes are designed to float when water levels rise, while anchoring in place under normal conditions. Emphasizing the use of locally sourced materials and community-centered construction methods, the project fosters sustainable development and local involvement, addressing safety and quality of life in areas frequently affected by flooding.

Isle de Jean Charles, Louisiana, USA (Ongoing)

The Isle de Jean Charles project in Louisiana tackles the challenges faced by this coastal community, which is experiencing severe land loss due to climate change. This effort centers on relocating residents to elevated areas, while incorporating adaptable and resilient design features that address future environmental impacts. The project strives to preserve the community's cultural heritage while equipping homes with features to endure flooding and other climate-related risks.

Leeville, Louisiana, USA (Ongoing)

The Leeville project in Louisiana is dedicated to creating adaptive living solutions for a community at risk of flooding and sea-level rise. This ongoing initiative incorporates amphibious housing that rises with floodwaters yet remains stable on land under regular conditions. Embracing sustainable techniques and community engagement, the project aims to foster resilient housing that meets the evolving climate challenges, while honoring local culture and way of life.

Friesland Floating Houses, Netherlands (Ongoing)

The Friesland Floating Houses project in the Netherlands demonstrates innovative floating residential designs. Emphasizing sustainability, these houses incorporate eco-friendly materials and energy-saving features, providing residents with comfortable homes that adapt to flooding. This project serves as a model for sustainable water-based living, promoting resilience in response to climate change.

Floating School and Community in Kisumu, Kenya (Ongoing)

In Kisumu, Kenya, the Floating School and Community initiative addresses educational needs in a flood-prone region. This project builds floating classrooms that ensure safe learning spaces for children, while also serving as hubs for community activities. Incorporating local materials and sustainable practices, the design encourages a sense of ownership among residents. The project emphasizes resilience through education and community involvement, enhancing local climate adaptability and social bonds.

Floating Food Forest, New York City, USA (2022)

The Floating Food Forest in New York City is an innovative urban agriculture initiative that promotes sustainability and local food security. This project features a floating garden with hydroponic systems to grow produce on urban waterways. By introducing green spaces into city environments, the Floating Food Forest aims to boost biodiversity and provide fresh food for nearby communities, showcasing how urban areas can adapt to climate challenges by rethinking water use and food production.

INFERENCES

From this research it is clearly evident that in the past decade, amphibious houses have undergone significant adaptations, evolving from basic designs focused primarily on buoyancy to more sophisticated structures that incorporate sustainable technologies, community engagement, and advanced flood-resilience strategies. From the analysis of various projects and research papers it was found that earlier projects, such as the Maasbommel Amphibious Homes (2005) [9]. emphasized foundational stability and simple flotation mechanisms while recent initiatives like the FLOAT Base (2015) and LIFT House (2018) integrate renewable energy systems, rainwater harvesting, and designs that prioritize community needs. This shift reflects a growing understanding of how to create resilient living environments that not only float during floods but also enhance the quality of life for residents.

Among the materials used across these projects, Expanded Polystyrene (EPS) stands out as a widely utilized choice for buoyancy due to its lightweight and effective properties. It is frequently employed in various structures like the LSU Prototype Amphibious House , Ban Khun Samut Chin etc. Reinforced concrete also remains a staple for foundations and structural components in many projects, including FLOAT House and Maasbommel. In comparison, bamboo has gained recognition for its sustainability and local availability, particularly in the Makoko Floating School. EPS has proven to be more effective than heavier materials in providing buoyancy while being cost-efficient, making it a preferred choice in various designs.

Recent projects have introduced innovative materials that enhance performance and sustainability. For instance, Hollow Ferrocement is used in the LIFT House for buoyancy, while Glass Fiber Reinforced Concrete (GFRC) in FLOAT House offers lightweight properties that improve structural efficiency. The incorporation of recycled plastic bottles into construction methods reflects a shift towards sustainable housing solutions, indicating an openness to new materials that complement traditional choices like EPS and reinforced concrete.

Strategies for flood resilience have become more sophisticated over time, with common approaches including buoyant foundations that allow structures to float during floods demonstrated effectively by the LSU Prototype and vertical guidance systems that ensure stability during water level changes, as seen in FLOAT House. Waterproofing techniques, such as watertight doors and ventilation systems to prevent water ingress, are crucial elements in designs like those of Ise City Houses. The most effective strategies identified include combining buoyant foundations with flexible utility systems that allow for disconnection during floods, enhancing overall resilience.

It was found that most researchers indicates an increase in flooding occurrences linked to climate change and anthropogenic alterations of landscapes. Some of the projects highlights the need for amphibious structures due to rising sea levels, underscoring a direct response to environmental changes. Among these projects, Maasbommel Amphibious Homes and FLOAT House have been recognized for their effectiveness due to successful implementation and resilience during floods. However, some projects had undergone redesigns based on initial feedback or unforeseen challenges.

Cost documentation varies among projects for instance, the LSU Prototype Amphibious House has reported costs of approximately $5,000 for its buoyancy system while most of projects have not made the overall cost of construction available for the public. Also it was found that projects like Ban Khun Samut Chin emphasize using locally sourced materials such as EPS blocks and timber frameworks to reduce overall construction costs while promoting sustainability. Several initiatives have retained traditional flood resilience techniques influenced by cultural practices, integrating local building styles with modern amphibious features.

Certain projects like The Buoyant Foundation Project was found to be retrofitting existing homes with buoyant foundations, allowing them to adapt to flooding without complete reconstruction. Most projects are operational today and continue to function effectively within their respective environments, providing valuable lessons for future developments. Ongoing operation and maintenance strategies of the projects involves community engagement to ensure that residents are trained in managing their floating homes effectively.

Projects constructed decades ago, such as Maasbommel Amphibious Homes, continue to function well due to robust design principles prioritizing resilience against flooding while integrating community needs into their development. These insights reflect a growing understanding of how amphibious architecture can adapt to changing environmental conditions while promoting sustainability and community involvement.

CONCLUSION

From this review of various amphibious structures around the world through more than 30 research papers it has been found that most of the researchers highlights a gradual shift towards more integrated, sustainable, and community-oriented designs. Most of the researches were focused on the materials used for the project however except a few, many lacked proper documentation of the overall cost of construction and operational maintenance as it is not made available to the public. The research demonstrates that amphibious structures, though rooted in historical practices, have evolved with technological advancements, now providing viable alternatives for flood-prone areas worldwide. From traditional stilt houses in the Amazon to advanced floating neighbourhoods in the Netherlands, these structures illustrate a harmonious blend of tradition and innovation. Furthermore, many projects emphasize resilience, showing that with adaptable designs, it’s possible to mitigate flood risks while maintaining cultural continuity.

In addressing the challenges posed by climate change, amphibious structures offer a sustainable approach that complements natural water cycles rather than resisting them. As communities face increasing flood events, most of these structures have proven to be an excellent adaptation strategy, demonstrating how design can both enhance resilience and support local communities’ needs. This study underscores the potential of amphibious structures as a key component in global flood resilience strategies, suggesting that further exploration and investment in these adaptable designs could profoundly impact vulnerable communities facing a future of rising water levels. With ongoing advancements in technology and materials, amphibious structures have the potential to become a cornerstone in sustainable urban planning and housing, providing scalable solutions for flood-prone regions worldwide.

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