Adapting To Flood and Sea-Level Rise through Amphibious Architecture in India

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Abstract
With climate change increasing the frequency and intensity of floods, India is one of the most flood-prone nations in the world. A potential answer to these problems is amphibious architecture, a design strategy that blends architecture and engineering to produce buildings that can adapt to the fluctuating water levels brought on by flooding or increasing sea levels. The historical context, difficulties and potential, design guidelines, and methods of amphibious architecture in India are all explored in this research paper. The paper explores the development of amphibious architecture in India, encompassing traditional and modern constructions, and assesses the benefits and drawbacks of this strategy. It finishes by underlining the significance of amphibious architecture in India and its potential to provide flood-resistant, adaptable, and sustainable structures that can endure the shifting water levels brought on by climate change.

Keywords: Flood, amphibious, resilient,

I. INTRODUCTION

India is one of the most flood-prone countries in the world, with nearly 40 million hectares of land affected by floods every year. With climate change causing sea levels to rise, coastal cities in India are facing an increased risk of flooding. In recent years, several major cities in India, including Mumbai and Chennai, have experienced devastating floods, causing loss of life and property damage. The need for innovative solutions to tackle this problem has never been greater.

The term "amphibious architecture" describes structures that can be used on both land and in water. Cities on coasts that are prone to floods now require amphibious construction. In India, amphibious architecture is becoming ever-more important as a result of the frequent floods brought on by monsoon rains and the rising sea level.

The issue of flooding in coastal cities has a viable solution: amphibious architecture. Amphibious structures are made to float on water when floodwaters rise, minimising the danger of damage to infrastructure and buildings. Several architects and designers have been experimenting with amphibious architecture in India, creating structures that can adjust to shifting water levels.

The importance of the thermal comfort level of human occupants affects productivity and metabolic rate. The non-uniform change in climatic factors is affecting human health based on various parameters. There are various models performed for analyzing the obstruction of human comfort in buildings. In this paper, there will be factors of thermal comfort along with the other human factors that are responsible for indoor environment quality.

The chapter includes a brief introduction of the theme of the research paper i.e., analysis of human comfort on the basis of various factors.

A. Aim and Objectives

The purpose of the study is to use amphibious architecture to develop amphibious structures that are resilient, ecological, and self-sufficient in order to adapt to flood and sea level rise. The main objective is to reduce the risk of flooding that the human settlements in India face and to design and construct a suitable amphibious architecture prototype;

B. Research Method

The research methodology involves the study of different flood mitigation dwelling styles, historical background, climatic analysis and the construction of amphibious structure according to the Indian context.

II. HISTORICAL BACKGROUND OF AMPHIBIOUS ARCHITECTURE

Amphibious architecture in India has evolved over the centuries in response to the country's unique environmental challenges, such as flooding, droughts, and rising sea levels. From the ancient Indus Valley Civilization to modern-day India, architects and builders have developed innovative techniques to create buildings that can withstand the forces of nature. In this essay, we will explore the evolution of amphibious architecture in India and how it has shaped the country's architecture and urban design.

The earliest examples of amphibious architecture in India can be traced back to the Indus Valley Civilization, which flourished from around 3300 BCE to 1300 BCE. The cities of Harappa and Mohenjo-Daro, located in present-day Pakistan, were built on a series of raised platforms and terraces, which allowed water to flow freely beneath the structures. The drainage systems of these cities were advanced for their time and helped to mitigate the impact of floods and monsoons.

In the centuries that followed, India had the establishment of numerous kingdoms and empires, each of which had an impact on the country's architectural style. India experienced the growth of ornate gardens, palaces, and tombs under the Mughal Empire's control from the 16th to the 19th century, many of which were constructed around water. Water features such as fountains, pools, and cascading waterfalls were popular in Mughal architecture, which is well recognised for its use of water.

In the state of Karnataka in southern India, the city of Hampi was constructed in the 14th century. The city was built on a series of elevated platforms and terraces, allowing water to flow freely beneath the structures, and it was intended to endure floods. The city's water management systems were innovative for their time and helped to mitigate the impact of floods and monsoons.

III. TRADITIONAL AND CONTEMPORARY AMPHIBIOUS STRUCTURE

Traditional amphibious structures are construction done to be used in both on- and off-the-water situations. These structures include boats, rafts, and amphibious vehicles and are typically built on stilts, with a lightweight platform or floor that floats on the water's surface during floods. These constructions, which have been around for millennia, are usually constructed out of materials like wood, bamboo, or animal hides.

These more up-to-date buildings are referred to as "amphibious structures" since they may be used on both land and in water. These structures are often more complex than conventional amphibious

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structures and are frequently composed of steel or reinforced concrete. They are designed to be fully amphibious, meaning they can rise and fall with changing water levels without sustaining damage. They are typically anchored to the ground and have a foundation that allows them to float. Amphibious homes, floating bridges, and amphibious vehicles are a few examples of modern amphibious buildings.

IV. CLIMATIC ANALYSIS

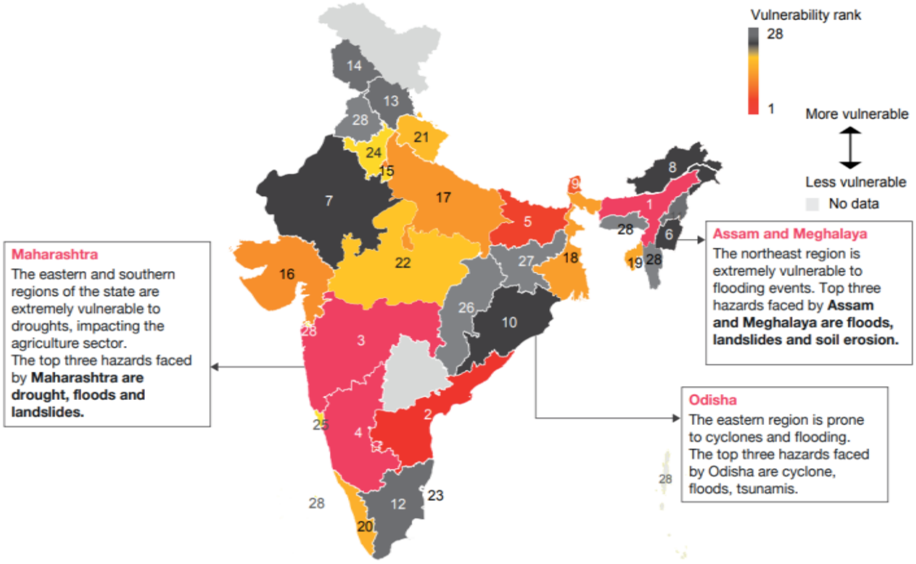
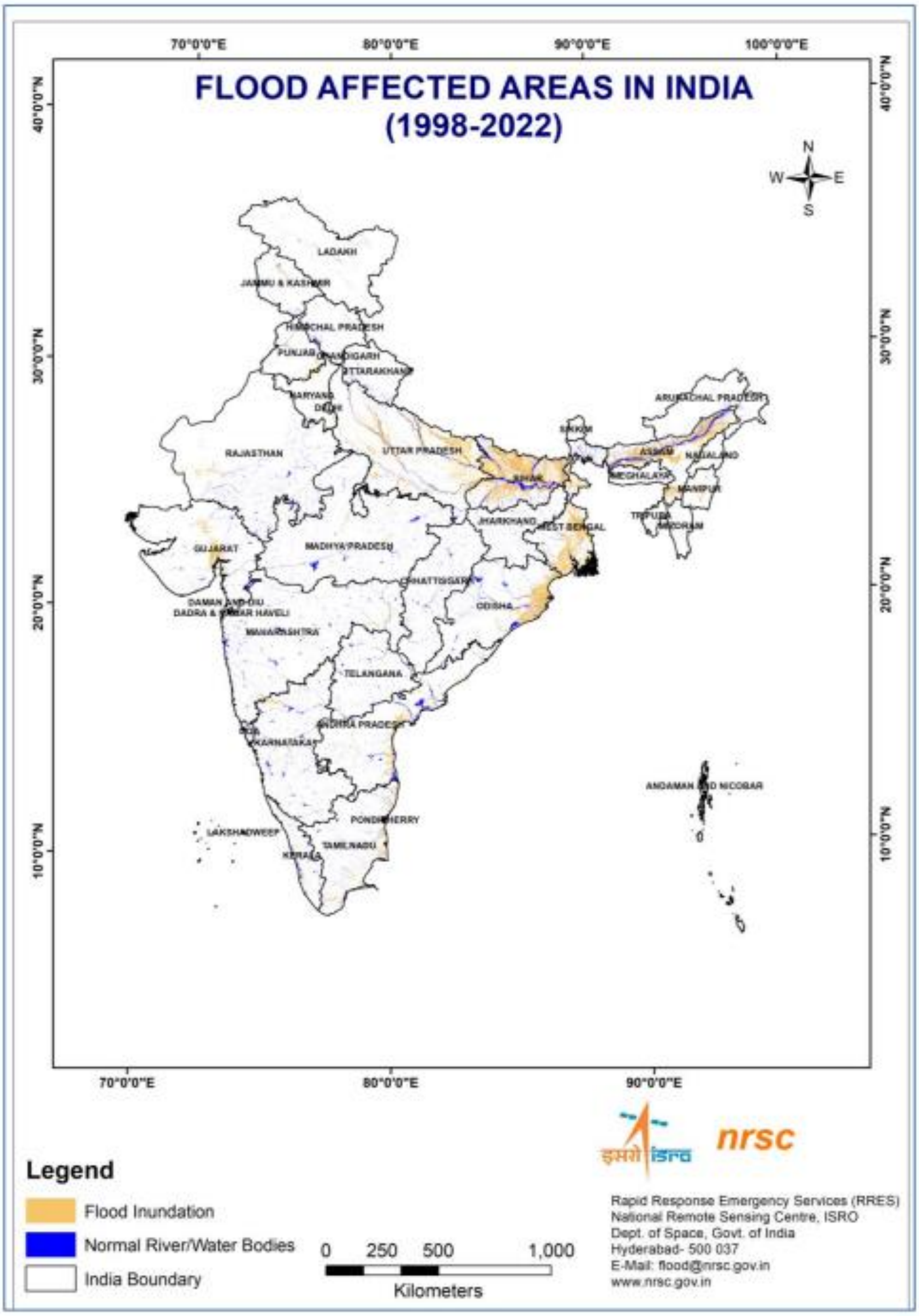


Figure 1 : Climate vulnerability profile of India

Source: Climate Vulnerability Index - Council for Energy, Environment and Water, CEEW, 2021

Floods have been among the most devastating climate related disasters, increasing in both frequency and intensity. Almost the whole of the Northeast region is highly vulnerable to flooding events. Several other states also have districts that have recorded a very high incidence of flooding events, including West Bengal, Uttar Pradesh, Kerala, Maharashtra and Gujarat. The mountainous states in Northern India are also prone to flash floods, brought about by extreme rainfall as well as melting glaciers. In 2019, the Union Minister for State informed the Rajya Sabha that India suffered losses to the tune of INR 95,736 crore in 2018 from floods alone, 2.6 times more than the losses in 2017.23 This increasing trend has been observed across most of the extremely flood-prone states. In Assam, around two million people on average were affected each year by floods before the 1990s. In 2020, this number was as high as six million and has been on the rise every year.



Disclaimer : Flood affected area map is a cumulative of flood inundation areas mapped from multi-date satellite data acquired and processed during 1998-2022 covering major flood & cyclone events. Flood inundation may include rain water accumulation / flood water in low lying areas. Estimated flood extent depends on availability of satellite data, it's date of overpass and coverage over flooded areas. Some of the Flash flood events could not be mapped due to non availability of satellite data in short duration. Flood affected area estimated in the study excludes river portion, permanent water bodies, salt pans and aquaculture lands in flood plains. Hence, actual flooded area may be more than the area estimated by satellite images.

Flood Affected Area Map of India as viewed by Satellite Images during 1998 to 2022

Figure 2 : Flood affected areas in India

Source:

https://www.nrsc.gov.in/sites/default/files/pdf/DMSP/Releasefloodaffectedareaatlas_sba_2023.pdf

Negative Impacts on Flooding

The following findings from the IPCC are summarized as follows;

- By the year 2100, it is anticipated that the mean sea level rise along the Indian coast will increase by 1.0 to 1.4 metres.
- Given the population of today, a 1.4 metre sea level rise will put 9,80,000 people at danger of a 100 year flood.
- A 100 year flood event will raise the risk of inundation for a variety of essential facilities, including highways, hospitals, schools, wastewater treatment plants, power plants, and more.
- An estimated 550 square miles of wetlands along the Indian coast are at risk from sea level rise, particularly if marine species is prevented from migrating farther inland by levees, bulkheads, seawalls, and other development.
- Property worth close to million could be at risk of flooding from a 1.4 metre high wave.

V. TYPES OF WATER DWELLINGS

Houseboats

The first houseboats appeared in Kashmir in the late 19th century. The authorities, used to the conveniences of home, hired local boat builders to build houseboats that would give them a cosy and familiar place to stay while they were touring the area.

Initially houseboats were constructed using deodar wood and woollen carpets, which are typical Kashmiri building materials and techniques for boats. The "kettuvallam," a traditional houseboat in Kerala, was once used to transport rice and spices around the waterways. These boats were totally built of wood, with bamboo walls and curving thatched roofs. As Kerala's tourism industry grew in the 20th century, kettuvallam started to be employed as a distinctive type of lodging for guests. The modern houseboats in Kerala now have a hybrid design that combines traditional and modern components. Although the boats still have bamboo walls and thatched tops, they are now constructed with more contemporary materials like steel and fiber-reinforced polymer.

Pile Dwellings

Pile dwellings are a type of housing that are built on top of concrete, steel, or wooden poles and are common in areas with shallow water, along the coast, or near lakes where it is possible to predict changes in the level of the water. The typical height of a home in this type is between 8 and 15 feet.

Concrete piles that are precast or cast in place might be plain, reinforced, or prestressed. Additionally, concrete is more accessible than steel and does not rot or decay like wood. Pre-cast concrete piles are moulded and moulded according to shape, length, and size before being driven into the ground, whereas cast-in-place piles are poured into holes in the earth where a rod has already been pushed and withdrawn. Though steel pilings can be formed in many different ways, the most common shapes have cross sections that are rolled circular, X-shaped, or H-shaped. They are quite strong and ideal for driving, especially on firm ground, and they are simply cut off and joined by welding.

Static Elevation

Elevating a house to a needed or desirable Base Flood Elevation (BFE) is one of the most popular retrofitting techniques.

The living section of a house will be above the most severe floods when it is adequately elevated. There are various elevation methods available. Generally speaking, they entail either by-

- Elevating the home and constructing a new foundation below it or,
- Leaving the house in its current location and either adding a raised level inside the house or a new higher story.

Terp Dwelling

A terp is a man-made hill that the area's earliest settlers built as a defence against flooding.Commonly constructed on top of these mounds, terp houses are distinguished by their low, compact architecture. They frequently have high roofs that are intended to shed rainwater and are built with brick or other locally produced materials.

As flood protection techniques have improved and the demand for raised housing has diminished, terp houses have become less prevalent in modern times.

Amphibious Dwelling

A kind of building known as an amphibious house can float or rise with rising water levels, making it resistant to flooding. These kinds of homes are becoming more and more common in regions that are vulnerable to flooding or rising sea levels as a result of climate change. There are many different types of amphibious homes, from those erected on stilts or columns and fitted with hydraulic lifts that may rise in the case of flooding to those built on floating platforms or pontoons. Their construction materials are equally important, with many architects and builders opting for durable, waterproof materials that can withstand prolonged contact with water.

VI. CONSTRUCTION OF AN AMPHIBIOUS STRUCTURE

Design Considerations

- Understand local flooding conditions.
- Choose the right dock materials.
- Select suitable building materials for your home, such as wood or steel beams, that can withstand water damage and erosion from high tides.

Steps for Construction

A. Preparing the Site

The first step in building an amphibious house is to prepare the site. This includes clearing away any vegetation and other obstructions, checking soil conditions and installing a dock if necessary.

B. Constructing the Foundation

i. The first step to building an amphibious house is to excavation of soil for the foundation. The soil should be loose and sandy, but not too soft or wet.

ii. Then reinforce the steel out the rebar rods vertically in four rows around the perimeter of your hole; to provide structural support and stability.

iii. Different kinds of systems can be installed in foundation to make an amphibious structure float. For example- installation of pontoon, hulls, hydraulic pump.

a) *Installation and working of hydraulic pumps*

➢ ***Installation***

- Select the location for the hydraulic pump: The initial stage is to select the site for the hydraulic pump installation. When choosing a location, it's crucial to consider accessibility for maintenance and repair work. The position ought to be close to the hydraulic machinery that the pump will be driving.
- Lay the groundwork: After choosing the place, the groundwork for the pump must be done. Making a flat surface for the pump to sit on entails excavating the area where the pump will be put. To maintain stability, steel bars should be used to support the foundation.
- Install the pump: The hydraulic pump can be placed following the preparation of the foundation. The pump needs to be positioned on the foundation and fastened with bolts. For successful installation, it's crucial to adhere to the manufacturer's guidelines.
- Connect the hydraulic lines: After the pump is installed, the hydraulic lines can be linked to the pump. The correct fittings and hoses for the system should be used to connect the hydraulic lines. To avoid any leaks, it's crucial to make sure the connections are tight and secure.
- Test the system: To make sure the hydraulic system is operating properly before use, it must be tested. This entails inspecting for leaks or faults and doing any required repairs. Checking the system's pressure to make sure it is within the recommended range is also crucial.
- Maintain the system: After the hydraulic pump has been installed and tested, it is crucial to keep the system maintained on a regular basis. This entails monitoring the hydraulic fluid levels, changing any hoses that are worn or damaged, and examining the system for any wears or damage.

➢ ***Working***

The components of a hydraulic pump assembly include a pump, a driving motor on top, and a foundation structure at the bottom to support the pump and motor assembly. An amphibious structure can stay on the ground with little to no change in appearance until a flood event occurs because the foundation is made to be buoyant. In the case of a flood, the structure's buoyant foundation system raises the entire building up and away from the rising floodwaters, shielding it from harm and protecting both the building and its contents. The hydraulic pump assembly functions by bringing water from the surrounding region and pumping it to a desired spot when it is fastened to the foundation of an amphibious structure.

b) *Installation and working of hulls*

➢ ***Installation***

- Design and Determine the design of the hull system: The first stage is to decide on the design of the amphibious structure's hull system. Based on the structure's specific requirements, including its size, weight, and intended purpose, a design should be created.
- Construction of the hull: a. Build the structural framework using the material of your choice. The hull will be shaped and supported by this framework. b. Form the hull: Cut out the hull shape and attach panels or sheets of the chosen material to the structure. To make sure that the panels are watertight, they should be firmly secured and sealed. c. Strengthening and reinforcement: To increase the hull's strength, add reinforcement components like bulkheads, ribs, or extra layers of material. d. Install access points: d. Install access points: Build hatches, doors, and windows into the

hull construction as essential access points.

- Lay the foundation: After the hull system design has been decided, the foundation for the structure must be laid. In order to do this, the area where the hull system will be put must be excavated, and a flat surface must be created for the hull system to sit on.
- Install the hull system: Once the base is ready, the hull system may be put in place. In order to create a continuous hull, this requires setting the hull sections on the base and welding them together.
- Install the propulsion system: The propulsion system can be installed once the hull system is installed. In order to do this, the propulsion system's engines, propellers, and other parts must be installed. It's crucial to make sure the parts are securely and correctly placed.
- Test the hull system: It's crucial to do a hull system test before using the amphibious structure to make sure it's in good working order. Making any required repairs entails looking for leaks or other issues.

➢ *Installation and working of Propulsion system for hull*

An amphibious structure with a hull has a propulsion system that gives it the ability to travel across water. The installation and operation of the propulsion system are described in the following way:

Installing the Propulsion System:

- Determine the type of propulsion system: The first step is to determine the type of propulsion system that will be used. This can include diesel engines, gas engines, electric motors, or a combination of these.
- Install the engines: Once the type of propulsion system has been determined, the engines can be installed. This involves mounting the engines securely to the hull of the amphibious structure.
- Install the transmission system: After the engines are installed, the transmission system can be installed. This involves connecting the engines to the propellers, which will provide the thrust to move the structure through water.
- Set up the control system: After the transmission system is installed, the control system can be set up. It includes installing the controls for the engines and transmission system, which will enable the operator to regulate the amphibious structure's speed and direction.

Working of the Propulsion System:

- Starting the engines: To start the propulsion system, the engines are turned on and the transmission system is engaged.
- Controlling the speed and direction: Once the propulsion system is started, the operator can control the speed and direction of the amphibious structure using the control system. This involves adjusting the throttle to increase or decrease the speed, and using the rudder to steer the structure in the desired direction.
- Moving through water: As the propellers rotate, they generate thrust that propels the amphibious structure through water. The hull of the structure provides buoyancy and stability, allowing it to move smoothly through water.
- Transitioning to land: When the amphibious structure reaches land, the propulsion system can be disengaged and the structure can be driven on land using its wheels or tracks.

In summary, the propulsion system in an amphibious structure with a hull provides the power to move the structure through water. It is installed by mounting the engines and transmission system to the hull, and is controlled using a control system. The propellers generate thrust that propels the amphibious structure through water, while the hull provides buoyancy and stability.

C. *Building the Walls*
D. *Installing the Roof*
E. *Installing the Windows and Doors*
F. *Finishing the exterior includes installing siding, applying paint or stain, and adding trim.*
G. *Finishing the Interior*
H. *Installing the Utilities*

Conclusion

The Amphibious architecture is a promising approach to address the challenges posed by floods, storms, and rising sea levels, which are becoming increasingly frequent and intense due to climate change. By designing buildings and infrastructure that can withstand flooding, float, or rise with water levels, architects and engineers can help mitigate the impact of these events on communities and improve their resilience.

It offers several advantages over conventional flood protection measures, such as flood walls and levees, which can be expensive to build, maintain, and repair. Amphibious buildings can adapt to changing water levels and avoid damage, reducing the need for costly repairs or rebuilding. This research paper also shows the construction of amphibious structure with technical details.

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